A STUDY OF THE RELATIONS BETWEEN VERBAL AND NONVERBAL BEHAVIOUR: DEVELOPMENTAL DIFFERENCES IN CHILDREN'S DIFFERENTIATION OF RESPONSE DURATION.

A thesis
submitted in partial fulfilment
of the requirements for the Degree
of
Master of Sciences in Psychology
in the
University of Canterbury
by
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University of Canterbury
1992

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ABSTRACT

The discovery of discrepancies between human and animal performance on standard reinforcement schedules has resulted in growing interest in the role of verbal behaviour in human operant responding. The verbal control theory states that discrepancies between human and animal responding result from the unique ability of humans to use verbal descriptions of contingencies as rules for the self-instruction of behaviour. In opposition to this theory, the epiphenomenal hypotheses state that verbal behaviour plays no role in mediating nonverbal responding. The present study was designed to examine the verbal control theory, and to explore a related claim that there is a delay of some years between the initial acquisition of language and the development of rule-governed behaviour. Children aged 4.5, 7 and 11 years-old performed a discrete-trials task requiring temporal differentiation of button press duration. Success on this task was compared when children were required to perform either a concurrent verbal or nonverbal interference task. The two interference tasks did not show a differential effect on responding for any age group. While this result fails to support the verbal control theory, support for the opposing epiphenomenal hypotheses is precluded by problems identified with the use of verbal interference tasks. In addition to the interference tasks, children's verbal formulations of the reinforcement contingency were assessed by the presentation of a verbal probe following each trial. For the two older groups of subjects, successful nonverbal performance was correlated with verbal identification of the contingency, while for the youngest group no such relationship was apparent. These results clearly support the claim that following the initial acquisition of language there is a period during which verbal and nonverbal behaviour are dissociated. It is proposed that this hypothesis is not dependent on the overall validity of the verbal control theory.

1. INTRODUCTION

> The importance of a science of behavior derives largely from the possibility of an eventual extension to human affairs....Whether or not extrapolation is justified cannot at the present time be decided. It is possible that there are properties of human behavior which will require a different kind of treatment. But this can be ascertained only by closing in upon the problem in an orderly way and by following the customary procedures of an experimental science. We can neither assert nor deny discontinuity between the human and subhuman fields so long as we know so little about either.... I may say that the only differences I expect to see revealed between the behavior of rat and man (aside from enormous differences of complexity) lie in the field of verbal behavior.
>
> (Skinner, 1938. pp.441-442)

For many years, it was assumed by researchers and theorists within the field of the experimental analysis of behaviour that basic behavioural principles, discovered in experimental work with animals[1], would hold equally well for humans (eg. Morse, 1966; Tolman, 1938; Whaley & Malott, 1971). Despite a clear agenda outlined by Skinner (1938), requiring the demonstration of continuity between the behaviour of animals and humans in the operant laboratory, the experimental analysis of human behaviour remained for some time a largely neglected area of research (Baron & Perone, 1982; Buskist & Miller, 1981).

Nevertheless, there were challenges to the assumption that human behaviour could be accounted for by behavioural principles discovered in the animal laboratory. One such challenge was the claim that the complexity of human behaviour could not be accounted for by basic behavioural processes studied with animal subjects:

> ...few psychologists would now accept that the best way to advance psychology was to study the behaviour of an arbitrarily chosen small mammal in a variety of artificial and contrived experimental paradigms. It is hard now to believe that anyone should seriously have thought that such experiments could tell us all we need to know about human development, perception, or intelligence.
>
> (Mackintosh, 1983. p. 1)

A second challenge, however, arose within the field of operant studies, from the limited attempts which had been made at the experimental analysis of human operant behaviour.

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[1]While it is acknowledged that humans are also animals, the labels "human" vs "animal" are used in preference to "human" vs "nonhuman animal" for ease of writing.

A central concern to experimental analysis of animal behaviour has been the study of reinforcement schedules and their relation to response rate and response patterning:

> Apart from the special theoretical importance of frequency of responding in time, schedules of reinforcement of discrete responses are important because they represent the most intensively studied and best understood body of information on the generation and maintenance of operant behavior. (Morse, 1966. p. 57)

Schedules of reinforcement define the contingency between response emission and reinforcer delivery. Given that schedule response patterns are fundamental to operant theory, comparable schedule performance by human and animal subjects would be central to establishing the continuity of behavioural principles. The failure to demonstrate comparable performance would cast serious doubt on the generality of findings from the animal laboratory as applied to human behaviour. In fact, such a demonstration has been elusive, with human subjects failing to replicate typical characteristics of animal responding on some standard reinforcement schedules.

1.1 Discrepant Findings in the Analysis of Human and Animal Schedule Behaviour.

In 1957, Ferster and Skinner published a large volume detailing the typical response patterns generated by many different reinforcement schedules using pigeons and rats as subjects (Ferster & Skinner, 1957).

Subsequent research with human subjects has, however, failed to replicate the typical response patterns of animal subjects on two types of schedules, namely the fixed-ratio (FR) and fixed-interval (FI) schedules. Most interest has focussed on the discrepancies with FI schedules. In addition to differences in the patterning of responses, human responding often does not show the sensitivity to change in schedule conditions characteristic of animal performance.

<u>a. Response patterns on FR and FI schedules</u>

On an FR schedule, a reinforcer is delivered immediately after every *n* th response. The characteristic pattern of responding with animal subjects consists of a pause after the delivery of the reinforcer (post-reinforcement pause), followed by an abrupt change to a high and constant response rate until the next reinforcer is delivered (Ferster & Skinner, 1957). As the ratio requirement is increased, an orderly increase in the length of the post-reinforcement pause is typically observed (Felton & Lyon, 1966). By comparison, studies with human subjects find a high, constant, response rate when an FR schedule is in effect, with a conspicuous absence of consistent post-reinforcement pauses (Weiner, 1964a, 1964b, 1969, 1970, 1982; Zeiler & Kelley, 1969).

Most interest, however, has focussed on the comparison of animal and human responding on FI schedules of reinforcement. On an FI schedule, the first response, after a given interval has elapsed, is reinforced. The typical pattern of steady-state responding for animal subjects on an FI schedule depicts a scallop, in which there is a pause after reinforcement followed by an accelerated rate of responding which terminates upon delivery of the next reinforcer (Ferster & Skinner, 1957; Lowe & Harzem, 1977).

However, the characteristic scallop pattern of responding has been very elusive with adult human subjects. Rather, two patterns of responding are typical. One is a high-rate pattern in which subjects respond at a high and consistent rate between reinforcements; the other is a low-rate pattern, the subject emitting only a few responses towards the end of the scheduled interreinforcement interval (Lippman & Meyer, 1967; Leander, Lippman, & Meyer, 1968; Weiner, 1969).

b. Insensitivity to change in schedule conditions

Studies of animal FI performance show that as the length of the interval is increased, the overall response rate decreases (Skinner, 1938; Wilson, 1954; Hanson, Campbell, & Witoslawski, 1962). A finer-grained analysis reveals three changes with increasing FI length (Skinner, 1938; Lowe & Harzem, 1977):

i. the post-reinforcement pause lengthens

ii. the relative post-reinforcement pause- which is the length of the pause as a proportion of the schedule interval length- decreases

iii. the running rate (the response rate when the post-reinforcement pause is not included) decreases.

With human subjects, however, there is no consistent effect on performance from changing the schedule parameter (Weiner, 1969; Lowe, Harzem & Hughes, 1978). While, in the case of low rate performance, response rate may decrease as a function of increasing interval duration, this is largely due to an increase in the post-reinforcement pause, with very low numbers (eg.

1 or 2) of responses per interval across schedule values (Weiner, 1969; Lowe, 1979).

In addition to insensitivity to changes in the schedule parameter, human responding has been shown to be insensitive to some instances of change in schedule type. In particular, performance on the FI schedule of reinforcement shows a strong effect of reinforcement history, which is not characteristic of animal research (Lowe 1979, 1983). For example, the high rate pattern of responding on an FI schedule typifies performance following prior exposure to an FR schedule, while previous exposure to a DRL (Differential Reinforcement of Low rate of responding) schedule results in low rate FI performance (Weiner, 1964a, 1969). These patterns persist despite extensive training with the FI schedule (eg. in Weiner (1964a) subjects were exposed to the FI schedule for a total of 15 hours). Moreover, the high rate pattern on an FI schedule following exposure to an FR schedule persists even when a cost condition is imposed on responding (Weiner, 1969,1970). Thus, given prior exposure to an FR or DRL schedule, the response rate on the FI schedule reflects that typical of the preceding schedule, even when this results in a reduction of the total reinforcement gained.

As previously stated, the failure to replicate typical patterns of animal responding and sensitivity to reinforcement schedules with human subjects challenges the assumption that findings from the animal laboratory can be generalized to the analysis of human behaviour (Weiner, 1983). It raises questions as to whether human behaviour can be accounted for by existing behavioural principles, or whether new principles are required. To begin to answer such questions it is necessary to seek out those variables responsible for the discrepant findings.

1.2. Variables Postulated to Account for the Discrepancies in Animal and Human Schedule Behaviour.

At least four factors have been postulated to be responsible for the differences between human and animal behaviour in the operant laboratory. They are:

a. Nature of reinforcer delivery

Matthews, Shimoff, Catania, and Sagvolden (1977) proposed that one variable accounting for the differences between animal and human schedule behaviour could be a methodological one, namely the nature of the reinforcer and its delivery. Specifically, they noted that usually in experiments with animals the reinforcer is consumed, hence the reinforcer elicits a consummatory response from the subject which is different from the response that is being reinforced, and thus interrupts ongoing responding. By comparison, the typical method for delivering reinforcement in experiments with human subjects is to add points to a counter. This reinforcer requires no response from the subject and does not interrupt ongoing responding.

They tested this hypothesis with an experiment in which subjects were paired for VR (Variable Ratio) yoked VI (Variable Interval) schedules. Sensitivity to the contingencies would be demonstrated by higher response rates for the VR subject as compared to the yoked VI subject. For some subjects (11 pairs), pressing the response key resulted in automatic increment of the points counter when reinforcers became available (no-consummatory-response- NCR), while for other subjects (5 pairs) reinforcer availability was signalled by the illumination of lights, and a separate button had to be pushed to add points to the counter (consummatory response- CR). One session was conducted for each pair of subjects.

While Matthews et al. claim that of the NCR pairs sensitivity was demonstrated by only two subject pairs, in fact response rates from the final quarter of the experimental session show clear discrepancies in the predicted direction for 3 of the 5 pairs. In the CR condition, contingency sensitivity is indicated by 8 of the 11 pairs. The conclusion that these data support the hypothesis seems unfounded.

In fact the hypothesis that the nature of the reinforcer delivery accounts, at least partially, for the differences between animal and human schedule performance is not supported by data from a number of studies which compared human performance on FI schedule components under conditions requiring a distinct consummatory response, and conditions where no consummatory response was required. In these studies the consummatory response was not exclusively or consistently associated with scalloped or sensitive responding to the FI schedule components, when compared with conditions which required no consummatory response (Harzem, Lowe, & Bagshaw, 1978; Lowe, Harzem, & Bagshaw, 1978; Lowe, Harzem, & Hughes, 1978). Thus a consummatory response is neither sufficient nor necessary for animal-like responding on FI schedule components.

b. Behavioural histories

Weiner (1969, 1982,1983), proposed that differences in the responding of animals and humans on basic reinforcement schedules are due to the varying reinforcement histories of human subjects. Unlike animal subjects, who usually are raised in controlled environments, human subjects come to the laboratory with behavioural histories which incorporate widely varying experiences. In particular, humans may have had more exposure than animal subjects to intermittent reinforcement schedules following long periods of extinction, and this may account for the persistence of human responding.

Weiner cites as evidence for his theory data regarding sensitivity to changing schedules of reinforcement, as outlined in the previous section. Thus behavioural history may be manipulated in the operant laboratory, resulting in uniform behaviour of human subjects. For example- while there is usually great variability in human FI performance with subjects unpredictably displaying high or low rate patterns of responding- the type of pattern displayed (high or low rate) can be controlled by prior exposure to an FR or DRL schedule respectively.

However, while reinforcement history has clearly been shown to affect the performance of human subjects on some schedules, it does not provide an adequate answer as to why discrepancies between human and animal responding occur (Lowe, 1979). Specifically, it does not clarify why reinforcement history has such a profound effect on the performance of human subjects compared to the effect on animal subjects. Clearly, when such a differential effect occurs, there must be a variable operating on one, and not the other, group of subjects which is unaccounted for. The missing variable may be found in the mechanism by which reinforcement history maintains an effect on human responding.

The other two variables which have been proposed as explanations for the different performances of animal and human subjects in the operant laboratory both relate to verbal behaviour- an obvious factor distinguishing humans from animals.

c. Verbal instructions

In the preliminary phases of an experiment, the responding of animal subjects is shaped by successive approximation so that the subject will emit the appropriate response for reinforcement, and also to enable schedule control of the subject's responses. Similar procedures have not always been successful with human subjects, and verbal instructions are frequently used to elicit the appropriate response (eg. button press) (Perone, Galizio, & Baron, 1988). Some authors have postulated that instructions to subjects may be at least partially responsible for the differences in human and animal operant behaviour (eg. Matthews et al. 1977).

d. Verbal self-instructions

Lowe (1979) has proposed that the variable responsible for the discrepant effects of reinforcement schedules and history on animal and human responding may be the covert verbalizations of the human subject. That is, human subjects in operant experiments may formulate verbal descriptions, or rules, concerning the contingency between responses and reinforcement delivery. The verbal formulation may then direct ongoing behaviour. As verbal formulations may be inaccurate or incomplete representations of the actual contingency, they may result in behaviour that is not optimal in terms of efficiency of responding and/or the amount of reinforcement that is earned. Rule-following may also prevent contact with the discrepancy between the rule and the reinforcement schedule. Thus the effect of reinforcement history on behaviour may be mediated by persistent verbal rules.

Experimental findings regarding the effect of instructions and self-instructions on nonverbal behaviour in human subjects will be reviewed in detail in later sections. For now, suffice it to say that as a result of discrepant findings in research on human and animal operant behaviour there has been growing interest in the role of verbal behaviour. Prior to this, verbal behaviour, while acknowledged theoretically in radical behaviourism, was largely ignored experimentally.

1.3. Rule-Governed Behaviour

Radical behaviourism and verbal behaviour

The acknowledgment of private events as worthy of systematic scientific investigation is one of the key points which distinguish Skinner's radical behaviourism from methodological behaviourism (Skinner, 1969; 1974;1984; Lowe & Higson, 1981; Hake, 1982). Skinner clearly stated that the issue of private events was part of the agenda for the experimental analysis of behaviour:

> An adequate science of behavior must consider events taking place within the skin of the organism, not as physiological mediators of behavior, but as part of behavior itself. It can deal with these events without assuming that they have any special nature or must be known in any special way. The skin is not that important as a boundary. Private and public events have the same kinds of physical dimensions. (Skinner, 1969- p.228)

Thus the notion of covert events as an important part of the behaviour of human subjects is integral to the theory of radical behaviourism. Covert, or private, events are seen as behaviours subject to the same laws and principles as observable behaviours and are not given special status as ultimate causal variables. Rather, like overt behaviours, they are environmentally determined.

Skinner identified an important subset of contingencies involving private stimuli as those contingencies operating within the verbal community. The mediation of reinforcement by members of this community is what distinguishes verbal behaviour from other behaviour (Skinner, 1957; 1984). While Skinner's early writings on verbal behaviour focussed most attention on the speaker (Skinner, 1957), later he looked more closely at the listener, and particularly the phenomenon of rule-governed behaviour (Skinner, 1969).

Rule-governed vs contingency-shaped behaviour

Skinner (1969) distinguishes between contingency-shaped and rule-governed behaviour. Contingency-shaped behaviour is behaviour which has evolved through a gradual process of shaping by reinforcement contingencies. All animal operant behaviour is contingency-shaped. But the verbal capacity of humans makes possible a class of behaviour known as rule-governed. Skinner defines rule-governed behaviour as behaviour under the discriminative control of verbal rules which specify the relation between antecedent stimuli, responses, and their consequences, or some combination of these variables. That is, rules are contingency-specifying stimuli, and rule-governed behaviour is behaviour under the discriminative control of such stimuli.

Rules offer several advantages to the rule-follower compared with contingency-shaped behaviour (Skinner, 1969;1974):

1. Shaping behaviour requires prolonged exposure to a contingency. Rules, on the other hand, can be learned quickly- and even without exposure to the contingency- by observation or transmission of rules by the verbal community.

2. Rules may be useful in circumstances where contingencies are too weak, too complicated, or too delayed to support appropriate behaviour.

3. Rules may make it easier to take advantage of similarities between contingencies.

However, as rules are rarely complete descriptions of contingencies, they do not engender the same behaviour as does prolonged contact with the reinforcement schedule. Even if rule-governed behaviour topographically resembles behaviour shaped by the same contingencies, the two forms of behaviour are nevertheless different, as they have different controlling variables.

Skinner's definition of rule-governed behaviour has engendered some debate. For example, it has been proposed that rules have a function not shared by other discriminative stimuli (Schlinger & Blakely, 1987; Vaughan, 1987; 1989). Namely, rules do not immediately evoke behaviour, but rather they change the probability that other stimuli will evoke particular responses. That is, they alter the functional relationship between other stimuli and responses. By comparison, discriminative stimuli do not have this function-altering effect, but rather their action is to evoke responses. It has been suggested that rules be classified as function-altering contingency-specifying stimuli- as opposed to discriminative stimuli (Schlinger & Blakely, 1987).

This analysis begs the question as to whether rule-governed behaviour is essentially different from contingency-shaped behaviour, and requires new principles and concepts to account for it. According to Skinner, rule-governed behaviour is subject to the same basic laws and principles as other discriminative stimuli. Brownstein & Shull, (1985) have suggested that while rules operate as discriminative stimuli, they may be much more complicated than other forms of discriminative stimuli. They may in fact, be discriminative stimuli for the operant class of rule-following. According to this analysis, the distinction between contingency-shaped and rule-governed behaviour is one of complexity, rather than between qualitatively different kinds of behaviour.

However, this definition seems to ignore the behaviour specified in the rule. A more thorough analysis is offered by Zettle and Hayes (1982), who proposed that rule-governed behaviour is behaviour subject to two sets of reinforcement contingencies. One set of contingencies is that which operates directly on the behaviour occasioned by the rule. The second set of contingencies includes a verbal antecedent and is mediated by the actions of other people. This set of contingencies reinforces rule-following *per se*. Zettle and Hayes offer the example of a person who is told to fast for a day as a situation where these two sets of contingencies are in opposition. While there may be nothing intrinsically reinforcing about fasting, the behaviour in this example may be maintained by the social contingencies for compliance with the rule. Thus, while rule-governed behaviour may be maintained by an apparent correspondence between the contingencies specified in the rule and the way the world is, it will also be maintained by special reinforcement contingencies mediated by the social community. In some instances the behaviour occasioned by the rule may have no other benefits to the individual emitting it.

This definition then treats rule-following as an operant independent of the behaviour resulting from rule compliance (Parrott, 1987). The rule is a discriminative stimulus for the operant class of rule-following. The rule may be conceptualized as not changing the functional relationship between the stimulus and response specified in the rule, as Schlinger and Blakely suggested, but rather it adds to the response a second contingency for rule-following.

The degree to which rule-governed behaviour is sensitive to the contingencies for the response specified in the rule will depend on the correspondence and comparative strengths of the rule and these contingencies. If the rule is at odds with the contingencies on the response it specifies, then the degree to which the resulting behaviour will be insensitive to these contingencies will be determined by the strength of the contingencies for compliance with the rule.

Thus the use of constructs such as verbal behaviour- both overt and covert- in the analysis of human behaviour is well grounded in the theory of radical behaviourism. However, despite this clear theoretical agenda, behaviourists for some time were at best reluctant to explore the relationships between verbal behaviour and nonverbal behaviour (Lowe & Higson, 1981; Lowe, 1983). Recently, however, there has been growing impetus to examine the relation between verbal and nonverbal behaviour in the operant laboratory. In particular, interest has focussed on the extent to which human behaviour is rule-governed, the role of verbal behaviour in rule-governed behaviour, and whether this accounts for the differences between human and animal operant behaviour. This inquiry has taken two lines. One has been to explore the effect of verbal instructions on subjects' nonverbal behaviour. The second has been to examine the role of subjects' own covert verbalizations.

1.4 Instructions and Human Operant Behaviour

The experimental analysis of instructional control enables the investigation of two issues:

a. The extent to which instructions to subjects account for the differences found between human and animal schedule behaviour. Unlike experiments in the animal laboratory, operant experiments with human subjects must involve some verbal interaction between the subject and experimenter, if not during, then at least prior to the experimental session. As previously mentioned, instructions are often used instead of shaping to elicit the appropriate response from the subject (Perone, Galizio, & Baron, 1988).

b. The relative contribution of rules and contingencies in the control of behaviour. The experimenter is able directly to manipulate the verbal stimuli in instructions and observe the effect this has on the nonverbal behaviour of the subject.

<u>Instructed vs shaped responding</u>

If discrepancies between human and animal performance on schedules of reinforcement result from procedural differences such as instructing human subjects, then following procedures used with animal subjects, such as shaping responses, should eliminate the performance differences.

Matthews, Shimoff, Catania, and Sagvolden (1977, Expt.1.) used a VR yoked VI schedule, as outlined previously, to compare the performance of subjects whose key press response was shaped, with that of subjects for whom key pressing to make reinforcement available was demonstrated (without vocal instruction). Two of the five subjects in the demonstration condition showed some evidence of discriminated response rates, either when compared with their yoked subject, or across within-subject changes in schedule type. The other three subjects did not display sensitive responding. Of the shaped subjects, 11 out of 13 subject pairs showed evidence of schedule-sensitive responding. According to Matthews et al. these results demonstrate that instructing the operant response results in reduced control by the reinforcement contingency, that is, contingency-insensitive responding. However, the results are somewhat confused by low subject numbers in the demonstration condition, and crossing with the previously discussed consummatory response/no consummatory response condition. In Experiment 2, subjects' key presses were shaped, following which they were exposed to an FI50s or FI60s schedule of reinforcement which required a button push (consummatory) response for reinforcer delivery. Contrary to the predictions of Matthews et al. this procedure did not result in the scalloped responding typical of animal FI performance, but rather in low rate responding typical of human FI performance. As the schedule parameter was not varied in this experiment, no conclusions can be drawn as to the sensitivity of subjects' responding.

Shimoff, Catania, and Matthews (1981, Expts. 1 & 2) compared sensitivity to the relaxation of a DRL contingency when key presses reinforced on a RI (Random Interval)15s DRL3s or RR (Random Ratio)4 DRL4s were shaped or instructed. Instructed subjects were told to press the key slowly. In both conditions a separate (consummatory), button press response was required to obtain reinforcements when they became available. With the RI schedule, removal of the DRL contingency resulted in an increased rate of responding for six of the eleven shaped subjects, and four of the ten instructed subjects. However, response rates remained relatively low, as with an RI schedule response rate and points earned are relatively independent of each other. In the case of the RR schedule, response rates increased for four of the six shaped subjects, and three of the eight instructed subjects. While response rates increased more slowly for the instructed subjects, the conclusion that "...instructions substantially reduced sensitivity to contingencies..." (p. 216) seems unwarranted. The data indicate that both sensitive and insensitive responding resulted from both shaping and instructing the key press.

Thus the evidence from comparing shaped and instructed responding does not convincingly demonstrate that it is the use of instructions to establish responding in experiments with human subjects which accounts for the differences in their performance when compared with animal subjects. It does indicate that insensitivity to changing schedule conditions may be at least partially due to instructional control. That is, instructions may establish rule-governed responding which under certain conditions may or may not be sensitive to changes in reinforcement contingencies. One way to examine the relative strength of the control exerted by verbal rules, in the form of instructions, and the control exerted by the programmed contingency is to examine the effect of inaccurate instructions on schedule performance.

Inaccurate instructions

A number of studies have compared the effects of no instructions, accurate instructions, and inaccurate instructions on operant responding. If responding conforms to inaccurate instructions, rather than the reinforcement contingency, then it is clearly rule-governed.

Kaufman, Baron, and Kopp (1966) compared the effect of minimal instructions, inaccurate contingency instructions, and accurate contingency instructions on VI1min schedule performance (Expts. I & II). Different instructions fostered quite different response rates which persisted over three hours of session time. Inaccurate FI contingency instructions resulted in scalloped responding for some subjects in early sessions. Thus instructions were important determinants of subjects' response patterns, and when FI instructions were given these promoted the elusive scalloped response pattern. A third experiment demonstrated that with contingency instructions subjects persisted in responding through a three hour session while in extinction. However, subjects who were given minimal instructions (which did not give any information as to reinforcement contingencies or even the required operant response) also persisted in responding through the three hour session. Thus instructions from the experimenter could not account for the insensitivity of responding to the extinction contingency.

Lippman and Meyer (1967) compared the performance on an FI20s reinforcement schedule of subjects who received no instructions (Group N) concerning the nature of the contingency between button pressing and point delivery, accurate interval schedule instructions (Group I), or inaccurate ratio schedule instructions (Group R). While the authors claim that the subjects in Group I all exhibited scalloped responding, individual cumulative records are not shown, and the number of responses average only approximately 2-4 per interval. This may indicate the predominant response pattern was actually low rate rather than scalloped. Most subjects in Group R responded at consistent high rates. Some subjects in Group N showed scalloping (this may also have been low rate responding), while others responded at a high rate. Thus it appears that interval instructions fostered the development of a low rate pattern, while ratio instructions resulted in high rate behaviour, although these results are based on low subject numbers (3 subjects each in Groups I and R), and a single experimental session.

Buskist, Bennett, and Miller (1981) exposed subjects, over a number of sessions, to an FI27s schedule. One group received no schedule-related instructions, while six other groups received instructions specifying a limited number of responses required for reinforcement, limited time available for responding, or some combination of these two factors. All of the uninstructed subjects exhibited a low-rate pattern of responding. Subjects instructed to restrict time responded at high rates with no, or very short, post-reinforcement pauses. Subjects with restrictions on number of responses showed a scalloped pattern of responding.

As with the experiment by Lippman and Meyer, this study showed that instructions could result in the development of the insensitive high-rate response pattern typical of human FI performance. For most subjects given inaccurate instructions, behaviour was governed by the rule provided by the experimenter rather than the reinforcement contingency. However, this experiment, if not also Lippman and Meyer's, showed that instructions could foster the scalloped response pattern typical of animal subjects. Kaufman, Baron, and Kopp's study demonstrated that FI instructions given when a VI schedule was in effect could also foster scalloped responding, at least in early sessions. Given that typical operant experiments with humans do not use inaccurate instructions, the claim that instructions account for the discrepancies in human and animal performance is unsupported. Furthermore, the third experiment by Kaufman et al. showed that uninstructed responding, as well as instructed responding, was insensitive to an extinction schedule. Thus the claim that instructions are responsible for the insensitivity of human responding is also not supported.

Varying schedule parameters and schedule sensitivity

Another way to assess the sensitivity of behaviour is to use multiple schedules and compare a subject's responses across components of the schedule.

Baron, Kaufman, and Stauber (1969, Expt.1) arranged a five-component multiple schedule for button press responses. Four of the schedule components were FI schedules of varying interval length (10-270s) and the fifth component was extinction. Subjects who received extensive instructions, including details about the nature of the interval schedule, and the interval length associated with each component signal, displayed responding which was sensitive to changes in the reinforcement parameter. Those subjects who did not receive schedule-related instructions displayed high rate responding which did not reliably vary across different FI values. Moreover, instructed subjects showed scalloped response patterns, while uninstructed subjects tended to respond at consistently high rates. Thus extensive contingency instructions promoted responding which appeared to be sensitive to changes in the schedule parameter, while uninstructed responding did not.

A similar effect of schedule instructions was found when subjects responded to prevent monetary loss on a four-ply multiple schedule, which consisted of three avoidance components (10, 30, or 60s) and an extinction component (Galizio, 1979, Expt.1.). Prior to receiving schedule instructions, only one of four subjects discriminated consistently between components. When instruction labels identifying the appropriate temporal parameter were placed above the component lights, the remaining three subjects rapidly developed sensitive responding. In the third phase, although the labels were removed, and the lights and components were shuffled, two of these three subjects maintained discriminated responding. These findings support those of Baron et al., in that contingency-related instructions promoted responding which was sensitive to different schedule parameters, whereas uninstructed responding generally was not. Moreover, learning a new discrimination was enhanced by exposure to instructions on a previous discrimination.

However, with both of these studies, the sensitivity to schedule components demonstrated by the subjects was in fact instructed. That is, subjects were given instructions as to how to respond to each contingency. A real test of sensitivity, given shaped or instructed performance on one contingency, is to introduce a second contingency without shaping or instructing the subject, to see if responding adjusts appropriately. One way to do this is to give instructions to a subject which are accurate for only one component of a multiple schedule.

Hayes, Brownstein, Zettle, Rosenfarb, and Korn (1986, Expt.1) compared performance of subjects on a multiple DRL6s FR18 schedule following minimal instructions; instructions to push the response button quickly; instructions to go slow; and accurate rate instructions. With minimal instructions, only one of four subjects exhibited differentiated response rates in the two schedule components. Subjects instructed to go slow exhibited slow response rates on both components, while half of the subjects instructed to press quickly showed responding which was sensitive to the two contingencies. The other two subjects in this condition responded at high rates for both components. All of the subjects who received accurate rate instructions quickly developed differentiated responding. Thus the instructed responding in the Go Slow condition was not sensitive to the contingency change, while for some subjects in the Go Fast condition, responding was sensitive.

Hayes, Brownstein, Haas and Greenway (1986) used the same basic procedure, but in the third and final experimental session all subjects were in extinction, although they were not instructed of this change in schedule. Although subjects in the accurate instructions condition all showed differential responding on the multiple schedule, only half of them showed large extinction effects (minimum 50% reduction in response rate). Thus, for half of the subjects the apparently sensitive responding in the multiple schedule condition was controlled by instructions. In the other conditions (minimal instructions; go slow; go fast) subjects who developed discriminative responding in the multiple schedule despite inaccurate, or no, instructions showed large extinction effects. Subjects who displayed schedule-insensitive responding did not. Therefore, instructed responding which appeared to be sensitive to contingencies in the multiple schedule was consistently found to be sensitive to extinction only when the multiple schedule performance could not have resulted from following a rule provided by the experimenter. Thus responding may appear to be contingency-governed, but in fact be rule-governed.

Determinants of sensitivity of instructed responding

The studies outlined above show that the degree to which instructed behaviour is sensitive to changes in reinforcement contingencies varies between subjects and with the type of instructions. Three hypotheses have been put forward to account for the apparent insensitivity, of instructed behaviour to reinforcement schedules:

1. Insensitivity is a defining and inherent property of instructional control (Shimoff et. al., 1981).
2. Instructions result in patterns of responding which prevent the subject from making effective contact with the contingency (Baron & Galizio, 1983).
3. Insensitivity may result from the introduction of competing contingencies related to compliance with instructions (Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986).

The claim that insensitivity is inherent to instructional control throws no light on why certain instructions prevent contingency control for some subjects, and not others.

One possible reason for this is that instructions which prevent contact with contingencies result in schedule-insensitive behaviour. That is, the degree to which instructions limit the range of emitted behaviour may determine the degree of contact with, and control by, contingencies. Galizio (1979, Expt. 2.) compared the effect of inaccurate instructions when behaviour corresponding to the instructions resulted in loss of money (contact- C) and when it did not (no contact- NC). In the first phase, subjects were given accurate contingency instructions and responded on a four-ply multiple schedule with three avoidance components and one extinction component. In phase 2 (NC) the instructions were unchanged, but no-loss was programmed for all components. Phase 3 was the contact condition, in which the instructions were again unchanged, but an avoidance schedule with a response-loss interval of 10s was in operation for all components. With accurate instructions, discriminated performance was rapidly established, and persisted through the NC condition. Instructional control rapidly broke down in the C condition, when following instructions resulted in loss of reinforcement, and control did not return with reinstatement of the NC condition. Thus inaccurate instructions maintained control over responding when this responding did not result in contact with the discrepancy between the instructions and programmed schedule. However, when such contact was made, instructional control was weakened. Thus in the contact condition, instruction-following was sensitive to consequences.

At first glance, this appears to have been the effect of instructions in the study (outlined above) by Hayes, Brownstein, Zettle, Rosenfarb, and Korn (1986, Expt.1). For example, go slow instructions were followed in both components of the multiple DRL FR schedule, and as high rates were never emitted, they could never be differentially reinforced. However, for some subjects, this was not the case- that is, unsuccessful responding persisted despite some contingency contact. The explanation that rule-governed responding is insensitive to changes in schedule because it prevents contact with the schedule is also unsupported by the results of Hayes, Brownstein, Haas and Greenway (1986), outlined above. In this experiment, all subjects made contact with the extinction contingency, but responding was not always sensitive to it. In these two experiments then, continued control by instructions may have resulted from a history of reinforcement for instruction-following *per se*.

Thus responding may be sensitive either to the contingency on the instructed response, or the contingency for instruction-following, or both. Topographically, it may be difficult to distinguish behaviours which have different functional bases. However, the results from Galizio's experiment suggest that, at least in some instances, limits to behavioural variability resulting from instructional control play a part in the insensitivity of responding.

Hayes, Brownstein, Zettle, Rosenfarb, and Korn (1986, Expt 2) tried to assess the degree of instructional control over responding due to contingencies on rule-following *per se* as opposed to the effect of the range of behaviour making contact with the contingencies. As in the first experiment, reinforcement for responding was programmed according to a multiple DRL6s

FR18 schedule. Instructions concerning response rate (go fast; go slow) were each written on one of two illuminable signs. Subjects were instructed to comply with a sign when it was illuminated. Some subjects only received go slow instructions, some received only go fast instructions; and the rest received both types of instructions during each component of the multiple schedule. For half of the subjects in each instruction condition, the instructions were discontinued after the first of three sessions. By withdrawing the instructions, Hayes et al. claimed to be decreasing the effect of contingencies associated with instruction-following as an operant, and isolating effects resulting from limited behavioural variability. Some subjects in the Go Slow condition showed schedule-sensitive responding, and others did not, responding at low rates in both components. This was unaffected by the withdrawal of the instructional stimuli. While more subjects developed differentiated responding in the Go Fast condition, the removal of instruction lights still did not affect schedule-sensitivity. Subjects who received both instructions showed control by instructional stimuli throughout, but when instructional stimuli were removed following the first session, contingency control rapidly developed. Thus when instructions promoted only limited contact with the contingencies, their removal did not result in discriminated responding. When they promoted contact with both schedule components, responding remained under the control of the instructions, but became appropriately differentiated upon their removal.

These results demonstrate that control by instructions results from both the limits placed on the range of behaviour emitted, and the strength of instruction-following as a response class.

The studies of instructional control of human behaviour show clearly that verbal instructions can strongly affect the performance of subjects on reinforcement schedules. For example, they can result in behaviour which is insensitive to changes in the reinforcement scheduled for the response. This insensitivity can be accounted for by postulating that instructed responding will override the response contingency if there is a strong history of reinforcement for compliance with instructions. However, while instructions have been shown to have major effects on nonverbal behaviour, they do not appear to fully account for the discrepancies between human and animal schedule performance. For example, shaping behaviour, instead of instructing it, does not always result in schedule-sensitive responding, and may be less likely to generate scalloped response patterns on FI schedules. In addition, instructions frequently have inconsistent effects on the performance of different subjects.

1.5 Covert Verbalizations and the Role of Self-Instructions

Lowe (1979) proposed that in the operant laboratory, human subjects are not only influenced by instructions from the experimenter, but can also talk to themselves, and their self-talk can act as verbal stimuli for rule-governed behaviour. That is, even if responding is shaped by the experimenter, it may in fact be rule-governed, with the verbal stimulus arising from the subject's own formulation of the contingency. Lowe claimed that these covert verbal formulations of schedule contingencies are responsible for the differences between human and animal performance in the operant laboratory.

Preliminary evidence for what has been labelled the "verbal control" theory (Pouthas, Droit, Jacquet & Wearden, 1990)[1] came from studies which compared FI schedule performance with subjects' post-experimental verbalizations of the contingency. Leander, Lippman, and Meyer (1968) had subjects rank different experimenter-provided responses to the question:"What is the condition for getting points?" following a session of responding on one of four FI schedules. The four responses provided specified exact time interval; varying time interval; exact number of button presses; varying number of button presses as the criteria for reinforcement. All of the subjects whose responding stabilized at a low rate chose time-based formulations of the reinforcement contingency, while 18 of the 23 subjects who exhibited a high rate pattern of button presses chose response-based formulations. In a similar vein, Lippman and Meyer (1967- outlined above), found that following exposure to an FI20s schedule, of the subjects who responded at a high rate, all but one stated that the contingency was related to number of responses. The other subject, and all subjects who responded at a low rate, verbalized time-based formulations of the contingency. Thus both experiments demonstrate a strong correlation between the pattern of responding on an FI schedule and the subjects' verbal formulation of the contingency, such that the low rate pattern is associated with a time-based formulation, and the high rate pattern is associated with a response-based formulation.

Lowe proposed that the effect of reinforcement history on human FI performance may also be mediated by self-instructions. With FR schedules, reinforcement does not occur until a given number of responses are emitted. According to Lowe, this makes it very likely that subjects will form response-based formulations of the contingency. Likewise, reinforcement does not occur

[1] The theory has also been labelled the "language hypothesis" by Hayes, Zettle & Rosenfarb (1989).

on DRL schedules unless subjects respond after a given time interval has elapsed, making interval-based formulations likely. However, reinforcement on an FI schedule will occur whether subjects respond at a high or low rate. Thus self-instructions formulated upon exposure to an FR or DRL schedule may mediate the observed persistence of the response pattern upon changing the contingency to an FI schedule (Weiner, 1964a;1969).

Lowe also postulated that the effect of instructions on behaviour may be mediated by their effect on covert self-instructions. For example, in Lippman and Meyer's study, subjects who received interval instructions all gave interval-based verbalizations at the end of the experimental session. Of the three subjects who received ratio instructions, two responded at a high rate and verbalized response-based formulations, while one switched to low rate responding and verbalized an interval-based formulation. Thus in all instances when responding conformed to instructions, the subjects' verbalization of the contingency did likewise, while in the one instance where a subject's response pattern did not conform to instructions, neither did the verbalized contingency.

Thus failure of instructional control may depend on the formation of incompatible self-instructions.

However, a problem with Lowe's hypothesis is that the evidence based on post-session report is correlational in nature and does not conclusively demonstrate a mediational role for covert verbalizations (Perone, Galizio, & Baron, 1988).

An opposing view: Epiphenomenal hypotheses

In opposition to the verbal control theory, the epiphenomenal hypotheses state that subjects' verbal formulations of contingencies play no role in mediating nonverbal responding (Verplanck, 1962). Rather, verbal rules arise from separate processes- for example, they may be by-products from subjects' observation of their own performance, or they may be *post-hoc* rationalizations provoked by questioning. (Greenspoon, 1963; Weiner, 1983). Thus although verbal behaviour does not mediate nonverbal behaviour, there may appear to be strong associations between the two.

One study appears to provide strong support for the epiphenomenal position. Verplanck and Oskamp (1956, reported in Verplanck, 1962) claimed to have demonstrated the dissociation of a verbal rule and the behaviour it was meant to be controlling. The experimental task was to sort cards, featuring different pictures and designs, to the left and right. Subjects were divided into three groups- *P*, *P* H, and P*H*. Those in the latter two groups were instructed to state on every trial, prior to placing a card, the rule being followed. Groups *P* and *P* H received verbal feedback ("right" or "wrong") according to whether the placement of the card was correct, whereas for Group P*H* feedback was determined by whether the correct rule was stated or not.

Results showed that while P*H* subjects correctly stated the rule on 94.2% of trials, they only placed the card correctly on 76.8% of trials. Conversely, subjects in the *P* H group correctly placed the cards on 71.8% of the trials, but only stated the correct rule on 48.4% of trials. Thus it appears that by independently manipulating the contingencies for the placement response and subjects' verbal rules, the two were dissociated. This result clearly supports the epiphenomenal position because it seems to demonstrate that verbal rules do not mediate nonverbal behaviour, but rather are independent of it.

However, in a later replication of the study, the results were shown to be attributable to a statistical and a task artifact, rather than the operation of reinforcement contingencies (Dulany & O'Connell, 1963). This study replicated the results of Verplanck and Oskamp. It also included a control condition for stimulus ambiguity, in which subjects were told the correct rule prior to sorting the cards. Rates of misplacement, given correct rule statement, for these subjects were comparable to rates for subjects in the P*H* condition (14.2% vs 17.4% respectively). That is, stimulus ambiguity could account for the apparent dissociation of rule statement and card placement for those subjects who received feedback based on their verbalization of the rule. For subjects in the *P* H condition, Dulany and O'Connell point out that simply by chance there is a 0.5 probability that a subject will correctly place a card. Verplanck and Oskamp did not allow for this, and when it is taken into account, together with the number of correct rule statements the subjects emitted, the number of correct placements approximates the expected value. Thus, by taking account of stimulus ambiguity and chance success with incorrect rules, the rates of correct rule statement and correct card placement do not deviate significantly from expected values, and any apparent dissociation cannot be attributed to manipulation of the reinforcement contingencies.

However, the task of refuting epiphenomenal hypotheses and demonstrating a mediating role for self-instructions is not an easy one. Several experimental approaches have been tried. These include the use of frequent verbal probes throughout the experimental session to examine the temporal sequence of verbal rule changes and nonverbal response changes, strategies to interfere with covert verbalization, and developmental studies comparing the performance of preverbal infants with verbal children and adults.

Time-course of changes to verbal and nonverbal behaviour

Post-session interviews or questionnaires allow no insight into whether changes to subjects' verbal rules precede or follow corresponding nonverbal behaviour changes. Showing that verbal changes consistently precede changes in nonverbal behaviour would provide support for the verbal control theory. The use of frequent verbal probes throughout an experimental session may enable tracking of the temporal sequence (Wearden & Shimp, 1985).

Wearden and Ward (1988, in Wearden, 1988) used such a procedure to examine the development of temporal differentiation in a response latency task. Subjects received verbal feedback over 50 discrete trials, and between each trial they wrote down their formulation of the criteria for good performance. While some subjects received neutral instructions, others were informed that the duration of the trial was important. Timing strategies were more frequently and consistently verbalized by subjects who developed accurate temporal differentiation compared to those who did not. Subjects who were not successful at the task tended to verbalize a greater number of varying strategies, and both their verbal and nonverbal behaviour was less consistent than that of successful subjects. Analysis of the temporal sequence for the verbal and nonverbal behaviour of successful subjects revealed that the emission of timing verbalizations tended to precede adequate temporal differentiation of response latency.

The demonstration in this study that changes in nonverbal behaviour followed corresponding changes to verbal behaviour supports the verbal control theory. However, the epiphenomenal position can be maintained by proposing that both verbal and nonverbal behaviour are determined by a common third variable, and that under particular circumstances, verbal behaviour may have a lower threshold for change (Wearden, 1988). What is required is a demonstration that interference with covert verbal behaviour changes nonverbal behaviour. For example, if verbal strategies (such as counting) mediate nonverbal performance in tasks requiring temporal differentiation of responding, then interfering with covert verbalizations should reduce performance accuracy.

Interference with covert verbalization

Two types of interference techniques have been used to explore the relations between covert verbal and nonverbal behaviour. They may be described as indirect and direct interference techniques.

a. Indirect Interference Studies

Some studies with human subjects have found scalloped responding on FI reinforcement schedules (Holland, 1957; Azrin, 1958; Laties & Weiss, 1963). All of these studies used a signal detection procedure. For example, Holland (1957) had subjects respond to observe deflections of a pointer on a dial. Subjects were instructed to reset the pointer as quickly as possible, and could only see the pointer by responding to light up the dial. Pointer resets were programmed according to FI schedules of varying parameters. Cumulative records show scalloped patterns for the observing responses.

Laties and Weiss (1963) proposed that on standard FI and FR schedules, human subjects may count covertly to mark out the interval length or number of responses. It may be this behaviour which results in performance discrepancies when compared to animal responding. Providing a signal to indicate when reinforcement becomes available makes counting unnecessary, and hence results in performances which are similar to those of animal subjects. This strategy for interfering with covert verbalization may be called indirect, as its function is to make covert verbalization redundant.

One way to make covert counting unnecessary is to provide response-dependent access to a digital clock. Lowe, Harzem, and Bagshaw (1978) compared the performance of subjects in a binary clock and digital clock condition, when observing responses on one panel (Panel B) briefly illuminated a clock signalling reinforcer availability on another response panel (Panel A). For the binary clock condition, reinforcement availability was signalled by an illuminated green circle on a white background, while at other times responding illuminated just the white ground. In the digital clock condition, responding resulted in the brief illumination of a clock which displayed the time passed since the previous reinforcement. Reinforcers were available on Panel A according to a DRL schedule of varying schedule values, making presentation of the green stimulus in the binary clock condition effectively on an FI schedule. At the completion of the experiment, each subject filled out a questionnaire. For all subjects, responding on Panel A was very efficient, with only one response for each reinforcer. The cumulative records for the observing responses on Panel B showed a "break-and-run" pattern for all binary clock subjects, such that following a postreinforcement pause there was an abrupt transition to a high response rate. This pattern was insensitive to changes in schedule value. By comparison, subjects in the digital clock condition showed a scalloped response pattern, with a gradual increase in the rate of responding following the postreinforcement pause. Moreover, for subjects in this group, there was a systematic decrease in response rate with increases in schedule parameter. In the questionnaire, all subjects reported that reinforcer delivery was related to the duration of the interval since the previous reinforcer. All subjects in the binary clock condition reported counting out the interval, while subjects in the digital clock condition did not.

Another study compared standard FI performance with performance on an FI (60, 180, 20, and 360s) schedule when the same response resulted in access to a digital clock and reinforcer delivery (SPC condition), and when different responses were required for access to the clock and reinforcer (TPC condition) (Lowe, Harzem, & Hughes, 1978). Subjects in the standard FI procedure showed inconsistent response patterns, with no evidence of systematic changes in performance with changes in the schedule parameter. For the two other groups, observing response patterns were scallop-shaped. While overall response rate did not vary with schedule parameter for the TPC subjects, running rate decreased as the FI value increased. For subjects in the SPC condition, both running and overall response rates were a declining function of increasing FI schedule parameter. For both groups, post-reinforcement pauses increased as FI length increased. In post-session questionnaires, subjects in the standard FI condition reported a variety of formulations of the reinforcement contingency. Following exposure to shorter intervals all four subjects related interval-based formulations, with three reporting counting strategies. Subjects from the digital clock groups reported that the contingency was based on time intervals, and that they used the clock to indicate when they should begin to press for points. None of these subjects reported counting out the interval.

Thus it appears, that in both of these studies, the provision of a digital clock interrupted covert counting, and this was associated with FI behaviour resembling that characteristic of animal subjects- namely responses formed a scalloped pattern and were sensitive to variations in schedule parameter. However, subjects in the binary clock condition of Lowe, Harzem and Bagshaw, counted and showed a break-and-run response pattern. Such patterns have been reported with animal subjects (Ferster & Skinner, 1957). However, the immediacy of the transition to a high constant response rate found with the human subjects would be atypical for animal responding (Lowe & Harzem, 1977), as is the insensitivity of responding. Lowe et al. proposed that in the binary clock and standard FI conditions, behaviour was rule-governed, with counting serving as the verbal stimulus governing responding. When counting was eliminated with the digital clock procedure, responding came under the control of response-produced temporal cues which were determined by the reinforcement contingency, and hence behaviour resembled that typical of animal subjects.

However, a continuing problem with the indirect interference studies is that the evidence regarding covert verbalizations relies on post-session report and is still largely correlational in nature.

b. Direct Interference Studies

In three studies, covert verbal behaviour was directly interfered with by requiring subjects to engage in a competing concurrent verbal task. The underlying assumption of this method is that two verbal activities can not be carried out at the same time (Peterson, 1969; Sokolov, 1972). Thus the influence of covert verbal behaviour on nonverbal responding can be attentuated by requiring a subject to perform a concurrent overt verbal task. The role of self-instruction is indirectly demonstrated by the resulting changes in nonverbal behaviour. Thus, compared with indirect interference methods, direct interference methods aim to prevent covert verbalization, as opposed to making it redundant.

Laties and Weiss (1962) examined the effect of requiring subjects to perform a concurrent subtraction task while responding on a DRL24s reinforcement schedule. They hypothesized that with DRL schedules human subjects count to estimate interresponse intervals, thus the addition of the concurrent verbal task should result in relatively poor temporal differentiation. Results showed that when concurrent subtraction was not required (Expt 1) 11 of the 14 subjects had a modal interresponse time of 24 to 28 seconds. With the addition of the concurrent task (Expt 2), only two subjects maintained modal interresponse times within this range.

In a second study, Laties and Weiss (1963) had subjects work on a signal detection task, to reset deflections of a pointer, programmed by a FI 100s LH 10s schedule. Five subjects periodically performed a concurrent subtraction task. These subjects had been instructed as to the frequency of deflections on the signal detection task. For two subjects(S1 and S5), performance was minimally affected by the concurrent subtraction task. During control periods, these subjects had counted out the interval, while during the subtraction task they used the size of the remainder as a guide to the duration of the interval. The response patterns of the other three subjects showed more disruption during the concurrent task, with erratic patterns of responding being demonstrated. For one subject (S3), initial exposure to the concurrent task resulted in interruption of the high rate response pattern and irregular scalloping. Two of these subjects (S3 and S4) continued to try and time the interval during the concurrent task, either by counting or using the number of subtractions as a guide.

A slightly different procedure was used for a sixth subject, who was not instructed as to the nature of the schedule, but rather was given prior exposure to a FI 150s LH15s schedule. When not performing the concurrent task, this subject exhibited a low rate pattern of responding, but during the subtraction condition a clear scallop pattern emerged. This subject reported counting out the control intervals and trying to use the size of the remainder as a cue to interval length in the subtraction condition.

Thus, direct interference with the subjects' ability to covertly count during exposure to an FI schedule, resulted in disruption to the high rate pattern of responding for most subjects. For one subject who was not instructed as to the temporal parameters of the schedule, concurrent subtraction resulted in scalloped responding, while irregular scalloping was observed for one instructed subject. However, in this study, subjects were able to use the remainder of the subtraction task, rather than counting, to mark out the length of the interval between reinforcements.

Lowe and Hughes (in Lowe, 1979), examined the effect of concurrently shadowing random numbers on standard FI performance, and FI performance in a digital clock condition. All subjects were instructed as to the temporal nature of the schedule. The schedule in effect was FI120s LH8s. In the control sessions, when the concurrent task was not being performed, subjects in the digital clock condition showed scalloped response patterns, while those in the standard FI condition showed pause-respond patterns, with a long pause after reinforcement preceding a rapid response rate terminating upon delivery of the next reinforcer. There was no systematic effect of the concurrent task on performance in the digital clock condition, while in the standard FI condition, shadowing resulted in a reduction of the post-reinforcement pause and an increase in response rate. Of the five subjects in this condition, all reported that during control phases they counted out the interval, and that counting was disrupted by the introduction of the concurrent task. Three subjects used alternative strategies to mark out the interval, two visualized a clock face, and the third used her fingers as an abacus. Subjects in the digital clock condition all reported using the clock to cue the length of the interreinforcement interval.

Thus in the latter two experiments, some subjects developed alternative strategies to counting out the FI interval when required to perform the concurrent task. The clearest demonstration of interference with covert counting comes from the first study by Laties and Weiss' (1962) and the uninstructed subject in their second study (1963). In the Lowe and Hughes study subjects were instructed, a condition shown by Laties and Weiss (1963) to possibly minimise the effect of concurrent verbalization. However, all subjects in the earlier study by Laties and Weiss (1962) were instructed as to the nature of the DRL schedule and in this study there was a strong interference effect from concurrent verbalization. Thus the role of schedule instructions in modifying the effect of concurrent verbalization is unclear.

The failure of the concurrent shadowing task to affect performance in the digital clock condition of Lowe and Hughes experiment supports the contention that both procedures have the same effect- namely they both disrupt covert counting on FI schedules. That is, the lack of effect demonstrates the convergence of the effects.

However, the procedures employed in the studies above do not enable separation of the effects on responding due to general disruption resulting from the requirement to engage in two tasks simultaneously, and the effects due to disruption of covert verbal behaviour *per se*. The verbal interference conditions are compared with control conditions in which there is no concurrent task. This does not enable any conclusions as to whether it is the verbal nature of the interference task which is responsible for the effects observed. Many other factors could be implicated- such as reduced attention to the target task or increased fatigue. To isolate the effect of verbal interference, a control condition using a concurrent nonverbal task is required.

Generally, direct interference methods have received little attention in the literature, and there are serious limitations with the existing studies. However, they have the potential to provide the most rigorous test of the verbal control theory because they are not correlational in nature.

Developmental studies

Another approach to attenuating the effect of covert verbal behaviour is to use a developmental paradigm. By definition, preverbal infants do not have the capacity to verbally mediate nonverbal behaviour and therefore, according to the verbal control theory, their behaviour should be directly controlled by reinforcement contingencies. Thus preverbal infants should demonstrate schedule response patterns that resemble those of animals, rather than the characteristic adult human response patterns.

Lowe, Beasty, and Bentall (1983) assessed the performance of two infants (9 and 10 months of age) on a range of FI schedules (10, 20, 30, and 50s).

Responding was shaped by successive approximations. The operant response was touching a metal cylinder, and reinforcers included food items and short presentations of music. The response patterns of the infants shared common features of animal subjects' FI performance. These included a gradual emergence of the final response pattern(with older human subjects the final form is usually rapidly attained); a scalloped pattern for the final response form; and schedule-sensitive responding.

Thus the findings of this study are consistent with the predictions that would be made from the verbal control theory, namely that preverbal infants, having no verbal behaviour to mediate responding, would show schedule performance which shared the characteristics typical of animal responding. Prior to this experiment, the youngest subjects who had participated in studies of FI or FR performance were approximately 4 years old (Long, Hammack, May & Campbell, 1958; Zeiler & Kelley, 1969; DeCasper & Zeiler, 1972). Schedule performance generally resembled that of human adults, although some subjects showed erratic FI and FR performances which did not resemble the characteristic response patterns of either animals or adult humans (Long et al.; Zeiler & Kelley).

Bentall, Lowe, and Beasty (1985) compared the FI performance of children of different ages. Subjects were divided into four age groups as follows:

Group 1. 7.5 to 9 years-old

Group 2. 5 to 6.5 years-old

Group 3. 2.5 to 4 years-old

Group 4. 6 months to 1.5 years-old.

The experimental apparatus for the group 4 subjects (n=4) was as described above (the data from the two subjects of the previous experiment were included in the results of this experiment); while subjects in Groups 1-3 pulled a lever for reinforcement consisting of illumination of lights, presentation of slides and music, and food items delivered by a puppet. Responding for all subjects was shaped, and schedule values ranged from FI 10 to 60s, with schedule changes occurring once stable responding was achieved on a schedule. Prior to introducing a new schedule value, subjects in Groups 1 to 3 were asked what made the puppet work. The oldest two groups of subjects exhibited response patterns typical of adult FI performance- either low or high rate patterns. Their verbal responses to the question about the puppet showed the same association with nonverbal response pattern as has been found with adult subjects. Namely, those children who exhibited the low rate pattern of responding verbalized a time-based formulation of the contingency, while those who showed a high rate pattern verbalized a response-based formulation. Subjects in the 2.5 to 4 year-old age group displayed varied, irregular, broken patterns of responding with occasional scalloping and occasional high-rate responding. The verbal responses were equally varied, with no relevant formulations of the contingency, other than that the puppet appeared when the lever was pulled. For the youngest group of subjects, the predominant response pattern was scalloping. With respect to schedule sensitivity, only the responding of the youngest group of subjects showed an orderly relationship with schedule parameter. The behaviour of the other subjects did not consistently vary with changing interval length.

Thus only the responding of the preverbal infants resembled that typical of animals' FI performance, in that scalloped response patterns and sensitivity to changing schedule values were apparent. The performance of the two oldest groups of subjects was typical of adult human FI performance, with responding taking either the high or low rate form, and a lack of sensitivity to change in the schedule parameter. The verbal behaviour of these subjects with respect to formulations of the contingency also resembled that of adult human subjects. The responding of the 2.5 to 4 year-olds did not resemble either the typical animal pattern, or the typical adult human pattern. Bentall et al. proposed that this may represent a transitional stage of responding, such that the limited verbal behaviour of these children could have interacted with responding, but was not sufficiently sophisticated to permit verbal rule formation.

Thus data from developmental studies appear to support the verbal control theory, in that preverbal infants demonstrate schedule performance which resembles that of animals, while older children show response characteristics typical of adult humans. However, developmental studies at best provide evidence of an emerging correlation between verbal and nonverbal behaviour. This does not conclusively demonstrate that the verbal system comes to control the nonverbal system. Many other variables change with increasing age, for example, attention, coordination, intellectual abilities, history of exposure to reinforcement contingencies. Therefore the apparent correspondence between the development of verbal behaviour and changes in nonverbal responding may, in fact, reflect changes in other causal variables (Perone, Galizio, & Baron, 1988). Thus, as with temporal sequence analysis, developmental studies provide limited evidence in favour of the verbal control theory.

A second feature of the data from developmental studies is that as children develop a verbal repertoire, there is a stage during which their verbal behaviour appears to be dissociated from their nonverbal behaviour. For example, in the study by Bentall et al. children in Group 3 did not emit task-relevant verbalizations. Thus if it is true that differences between animal and human responding result from the ability of humans to self-instruct, there may be a stage in the development of this ability during which young children are not able to mediate nonverbal behaviour by the formation of verbal rules, even though their verbal repertoires are quite well developed. This hypothesis has been previously proposed within Russian psychology.

1.6. Luria: Self-Regulation and Private Speech

The suggestion that there may be a transitional stage in the development of verbal mediation of nonverbal behaviour, such that verbal behaviour is independent of nonverbal behaviour, is a feature of the theory posed by Luria concerning the genesis of voluntary behaviour (Luria, 1932; 1957; 1959; 1960; 1961a & b; 1981). Grounded in the Russian neurophysiological paradigm of human behaviour, the theory states that voluntary behaviour results from the development of verbal self-regulatory mechanisms. These self-regulatory mechanisms have their origin in the verbal interactions between adults and young children.

According to Luria, in the adult human, speech plays a key, regulating role in the organization of behaviour. It is the involvement of the verbal system- with its abstracting and generalising functions- in the formation of new cortical connections which distinguishes the behaviour of humans from that of animals, and enables voluntary control of behaviour. The inclusion of the verbal system in the formation of new associations changes their nature. Compared to more primitive associations, those which include a verbal rule do not require continued reinforcement for their maintenance, may be rapidly acquired, and may be rapidly changed.

Unlike the reactive processes of the adult, those of the young child are characterized by diffusion and impulsiveness. Sensory stimulation results in the direct excitation of the motor cortex, leading to motor responses. There is no"functional barrier" to control the passage of excitatory impulses into the motor cortex. Self-regulation requires the maturation of the neurodynamic system and the development of higher regulatory systems (the functional barrier) to inhibit and control incoming excitatory impulses. According to Luria, the development of the functional barrier, and the control of excitatory processes, is dependent on the development of speech. It is the verbal system which provides the functional barrier.

The development of self-regulation through speech proceeds along two dimensions. The first dimension is related to the form of verbal control, namely that control progresses from a simple impelling function to regulation based on the semantic aspect of speech. The second dimension relates to the source of verbal control, which progresses from control by overt speech to covert control. Luria incorporated these dimensions in a four-stage model of the development of self-regulation:

Stage 1 (1.5 to 3 years-old)- nonverbal behaviour is regulated solely by exteroceptive feedback, the child's own speech has no regulatory function.

Stage 2 (3 to 4 years-old)- the child's own speech has a simple impulsive function in initiating nonverbal behaviour. The early impellant function is due to the direct excitation of the motor cortex by incoming speech signals. The semantic aspect of speech does not regulate behaviour at this stage.

Stage 3 (4 to 6 years-old)- the semantic aspect of the child's speech begins to play a regulatory role. There is a gradual transition from control by overt speech to control by covert speech.

Stage 4 (6 years on) - covert, internal speech now plays an essential and integral role in the regulation of nonverbal behaviour.

Luria supported this developmental model with data from a series of experiments. In these experiments children were presented with a series of light signals of the same colour, and were instructed to coordinate squeezes of a hand-held rubber bulb with the signals (single-signal procedure)[1]. A variation of this procedure (dual-signal procedure) was to present light signals of two different colours (eg. red and green) and instruct children to squeeze for one colour (the positive signal) and refrain from squeezing for the other (the negative signal). The occurrence of signals and bulb-press responses was recorded on a kymograph.

Initially (Stage 1) children can not use their own verbal behaviour to control their actions, but rely on external control. That is, the verbal and nonverbal

[1] The descriptive labels applied to the procedural variations are created here for ease of reference.

systems are dissociated, and while speech may accompany behaviour, it does not control it. For example, when 2 to 3 year-old children were exposed to the single-signal procedure they typically responded continually, and the responses were not coordinated with the signal (Yakovleva, in Luria 1961b). Requiring the children to say "Go!" when the light signal flashed did not improve the coordination between the light signal and the bulb press. Rather, this intervention frequently inhibited bulb pressing, as children of this age were unable to coordinate simultaneous verbal and nonverbal responses. However, although children in Stage 1 are unable to verbally regulate their own behaviour, the simple impellant function of speech does appear in response to the speech of others during the second year. Instructions from others may initiate action, but cannot stop an action once it has begun. Thus the stimulating function of speech develops before its inhibitory function does. Luria(1961b) illustrated this claim using the single-signal procedure with children aged 18 months to 2 years. While instructions to squeeze the bulb resulted in squeezing, instructions to stop squeezing were ineffective. In fact, they often resulted in an intensification of squeezing. According to Luria this is because the instructions served a simple impelling function.

Thus at this stage of development, instructions from others may serve a simple impelling function and initiate activity, but they are unable to inhibit responding once it has begun. Behaviour is controlled by exteroceptive feedback. The child's own verbal behaviour operates independently of the nonverbal system, and attempts to coordinate verbal and nonverbal responses may disrupt responding.

By the age of three to four years (Stage 2), a child can begin to respond appropriately in response to instructions on the bulb-press task. For example, when children of this age were continually instructed when to press and when not to press the bulb, their responding was coordinated with the light signal (Paramanova, in Luria, 1961b). When instructions were not given in this way, responding was uncoordinated, with perseverative responses occurring between signals. Thus verbal signals from others begin to acquire an inhibitory function at this age. To investigate the action of children's own speech, subjects were told to accompany each press in response to the signal with their own verbal command "Go!" (Luria, 1961b). Whereas this procedure had failed with the younger children, three to four year-olds were able to coordinate the verbal response with the signal, and perseverative responding was almost eliminated. If the children stopped using the verbal accompaniment, uncoordinated responding reappeared. Thus the children's verbal responses regulated the emission of the bulb press response in a way that previously only external signals were able to.

The mechanism of action of the verbal stimulus was investigated by instructing the children "When the light appears, press twice". Children showed an inability to maintain appropriate responding following this instruction, with perseverative responding emerging again. If, however, the children accompanied the signal with the verbal response "Go! Go!" double presses emerged. However, it is unclear with this self-instruction whether the semantic or the impulsive functions controlled responding, as both would result in double presses. To determine which function was controlling nonverbal responding, the children were instructed to say "I shall press twice" when the light flashed. According to Luria, "I shall press twice" provides one impulse, whereas the semantic function defines two presses. In this instance, children responded with only one bulb press (Tikhomirov, in Luria, 1961b). Luria concluded that at this age, the child's own verbal signals operate by a simple impelling function.

This was further demonstrated using the dual-signal procedure (Tikhomirov in Luria, 1961b). With no verbal accompaniment 3 to 4 year-olds found it difficult to refrain from pressing to the negative signal. When instructed to say "Press" to the positive signal and "Don't Press" to the negative one, the former instruction resulted in coordinated responding, whereas the latter resulted in disinhibition of responding. Nonverbal responding complied with instructions only when the children were told to say "Press" to the positive signal and to remain quiet on presentation of the negative signal. This again supports the contention that children's verbal behaviour at this age operates impulsively to initiate responding.

With subsequent stages (Stages 3-4) the semantic aspect of speech comes to control nonverbal responding. There is a simultaneous shift from control by overt speech of the child, to control by covert verbal rules. Children of this age can comply with the instruction to press for one signal, and refrain from pressing for the other. The self-instruction "Don't press" functions semantically and inhibits responding. Impulsive reactions to signals no longer appear. When tasks are difficult, the use of overt speech to regulate behaviour may reappear, but speech still functions by semantic control. The development of verbal self-regulation of behaviour is complete by about 8 years of age.

Thus there is an apparent convergence between the experimental evidence put forward by Luria and the developmental studies arising from the verbal control theory, suggesting that while verbal behaviour distinguishes human and animal behaviour, there is a stage in development during which children are verbal, but their verbal responses can not mediate nonverbal responding. However, replications of the studies carried out and reported by Luria have not always supported the stage theory.

Replications of Luria's key experiments

A problem with the studies Luria presented in support of his stage theory, is that the experimental procedure was not standardized. For example, stimulus durations and interstimulus intervals were not uniform (Jarvis, 1968). This unstandardized manner of conducting experiments increases the chance that experimenter bias could have influenced the results. Several attempts have been made by Western psychologists to replicate the studies under more controlled experimental conditions.

The key experimental findings which would support Luria's theory are:

(i) Self-instruction conditions should not aid performance for Stage 1 children, and may in fact disrupt responding due to an inability to coordinate the verbal and nonverbal response systems.

(ii) Stage 2 children should be identified by conditions in which self-instructions are given which have incongruent semantic and impulsive functions. According to the stage model, they will respond on the basis of the impulsive function of the verbal stimulus.

(iii) Children in Stage 3 should show improved performance with overt self-instruction, and should respond in a way which is consistent with the semantic aspect of the instruction.

(iv) At Stage 4 overt self-instruction should have no effect on performance, which is covertly controlled. The exception to this is when tasks are difficult, in which case overt self-instructions may improve performance.

A number of studies have apparently replicated the findings reported by Luria. Joynt and Cambourne (1968) compared performance of children aged from 1yr 6mnths to 7yrs 7 months on the single-signal task with one or two presses required for each signal, and the dual-signal task. In the first of four conditions, the experimenter provided verbal instruction throughout the task (ESO); in the second condition, the subject self-instructed with words that had the same impulsive and semantic function (SAS-A); in the third condition subjects self-instructed with words for which the semantic and impulsive functions were incongruent (SAS-B); and the fourth condition was a silent condition (X). The subjects were arbitrarily divided into four age groups (mean ages are not reported), and were also grouped according to performance on the

Illinois Test of Psycholinguistic Abilities (ITPA). In reporting results the authors claimed that, based on age groupings, there was a tendency for performance to improve with increasing age, but that this tendency was more marked when the comparison was made by ITPA groupings. The developmental stage to which individual subjects belonged was not readily apparent, except for those with low "language ages" (Stage1) and those with language ages of 88 months or more (Stage 4). Most other subjects exhibited varying degrees of correct responding under each condition. By using the ITPA-based groupings, Joynt and Cambourne provided approximate language-age ranges for the different stages in Luria's model. They claimed that the results showed a stronger relationship between stages and psycholinguistic development (as measured by the ITPA) than between stages and chronological age. However, the results are difficult to interpret as age boundaries are not defined and the authors do not present sufficient data to support the claims they make (Bloor, 1977). In addition, they present no statistical measure as to the reliability of their classifications, or the apparent differences in performance between subjects assigned to different stages. The study, therefore fails to provide a rigorous assessment of Luria's model (Wozniak, 1972).

Beiswenger (1968) repeated the dual-signal task with subjects ranging in age from 3 years 5 months to 6 years 6 months. The interstimulus interval was randomly varied between 1 and 3 seconds. Unlike Joynt and Cambourne's study, there was no variation of verbal condition. Throughout the experiment the silent condition was in effect, and instructions from the experimenter were given only once prior to the onset of the session. Results showed a significant improvement, with age, of performance on both tests. Thus older subjects complied better with the verbal instruction from the experimenter than did younger children. However, the age range of subjects in this experiment is very narrow, and does not allow replication of the effect of instructions on behaviour for children across all stages.

Rondal (1976, Expts. 1-5) conducted a series of five experiments with subjects ranging in age from 3 to 7 years-old. Each experiment was defined by different instructions to the subjects, while within each experiment four different conditions were in effect. In Condition A subjects were required to perform the motor task only; in Condition B they were required to perform the verbal task only; in Condition C they were required to perform both together; and Condition D was a replication of Condition A.

Experiment 1 was a replication of the single-signal procedure, with the verbal response being "Press". Results showed that for Condition C, there was a significant decrease in perseverative responding for children aged 3.5 to 4 years. The perseverative responses reappeared in Condition D when the motor response no longer had the verbal accompaniment.

In the second experiment, subjects were instructed to press the bulb twice for each light signal. The verbal response in this experiment was "Press, press". This significantly decreased perseveration for subjects in between 3.5 to 4 years, and between 4 to 4.5 years. Experiment 4 was a replication of this experiment, but the verbal response was changed to "two". Thus in this experiment the semantic and impulsive functions of the verbal response were incongruent. This resulted in a significant increase in errors for 3.5 to 4.5 year-old subjects when compared with Condition C in Experiment 2, indicating that for these subjects responding was controlled by the impulsive function of the verbal response.

The third and fifth experiments replicated the dual-signal procedure. For both experiments the verbal response was "press" for the positive signal. For the fifth experiment the verbal response to the negative signal was "No", while there was no verbal response to the negative signal for the third experiment. Children in the youngest age group (3 to 3.5 years) were unable to establish the appropriate verbal patterns. Performance was significantly enhanced by the verbal response for the 3.5 to 4 year-olds, with no evidence of disinhibition of responding resulting from the verbal response associated with the negative stimulus. While there was a trend for the verbal response to the negative stimulus to improve performance of the older subjects, this was not significant.

Thus Rondal replicated a number of findings cited by Luria. These include improved performance for 3.5 to 4 year-olds in the single-signal procedure with self-instruction, but demonstration in the dual-signal procedure that for children of this age self-instructions operate impulsively. For younger children (3 to 3.5 year-olds) verbal self-instruction did not improve performance, supporting the hypothesis that the verbal and nonverbal systems of these children are independent. The one finding not congruent with those reported by Luria was that in the dual-signal procedure, the verbal accompaniment to the negative signal failed to disinhibit responding for the 3.5 to 4 year-old children, which one would expect if language is operating according to an impulsive function. This discrepancy may arise from the particular verbal stimuli used. Tikhomirov (in Luria, 1961b) used "Don't Press". The verbal stimulus "No" is more common and may acquire its semantic function at an earlier age.

The studies by Rondal, Beiswenger, and Joynt and Cambourne provide limited support for Luria's stage theory. Joynt and Cambourne's study claims to demonstrate all four stages, but little evidence is provided of this, with the results being presented in a descriptive form. Rondal's study is the most thorough replication supporting Luria's findings. However, other attempts at replication have failed to support Luria's stage theory.

In one study (Jarvis, 1968), the performance of children of four different age groups (Groups I to IV- mean ages 46.8mths, 59.5 mths, 71.6 mths, and 80.7 mths respectively) on the dual-signal procedure was compared across three conditions: the silent (X) condition; the "push" (P) condition in which subjects were instructed to say "push" prior to pushing for the positive signal; and the "don't push" (DP) condition in which subjects were instructed to say "don't push", and refrain from pushing, for the negative signal. In this study a button-press response was substituted for the bulb-press response. According to the stage theory, for subjects in the youngest group (Stage 2), there should be perseveration of responding in the X condition, which is reduced in the P condition, but the DP command should act impulsively and result in increased pushing. In older age groups coordinated responding would be predicted for all conditions, although performance in the silent condition may improve from Group II to IV. While results showed that task performance improved with age, they failed to show a difference in the effect of conditions across the age groups. Jarvis interpreted this failure as indicating that the results reported by Luria were an artifact of the uncontrolled experimental procedure he and his colleagues employed. However, there are at least three problems with Jarvis' procedure. The first problem is the restricted age range of the subjects, with the youngest group having a mean age of 3 years 11 months. The inclusion of younger subjects may have produced results more in line with Luria's (Miller, Shelton, & Flavell, 1970). The second problem is that the average interstimulus interval was only 0.78s. Such a short interval would mask perseverated responding(Wozniak, 1972). The third problem with the procedure is that prior to the start of the experimental session a practice session was conducted during which mistakes by the subjects were corrected by the experimenter until a criterion performance of correct responses (including no perseveration) to six consecutive positive stimuli was reached. Thus potential differences in performance between subjects were to some extent selected against by the training criterion, and may have been further masked by the interstimulus interval.

Miller, Shelton, and Flavell (1970) repeated the dual-signal procedure with subjects ranging in age from 3 years to 5 years 4 months. Subjects were each assigned to only one of four experimental conditions, in order to eliminate carry-over effects. Condition 1 was a silent condition; in Condition 2 subjects were instructed to say "Squeeze" to the positive signal and then press the bulb; in Condition 3 subjects were instructed to say "Don't squeeze" when they saw the negative signal; in condition 4 subjects were instructed to say "Squeeze" for the positive signal and "Don't squeeze" for the negative signal. The average interstimulus interval was 1.5s. Subjects were trained on the task until the experimenter was satisfied that the instructions were understood, and the subject was cooperating. Results showed that performance improved with age, but failed to show an age by condition interaction. This clearly does not support Luria's stage theory which would predict that the experimental conditions should have different effects on subjects of different ages, specifically, that the verbal response to the negative signal should have disinhibited responding for 3 to 4 year-old subjects. Furthermore, for no age group did saying "Squeeze" on the positive trials improve performance. That is, speech did not facilitate performance on the positive trials.

An analysis of verbal and motor response sequence revealed that for all age groups the predominant pattern was for subjects to press the bulb before verbalization, even though subjects were explicitly instructed to speak first. While this appears to be in conflict with Luria's theory, examination of the data presented by Luria (1961b) reveals that this temporal sequence was not uncommon in experiments he reported. Luria (1960) acknowledges this, but dismisses it as evidence of immature coordination of the two response systems.

Miller et al. postulated that Luria's findings may be an artifact of his particular methodology. In particular, the distinction between an impulsive and semantic function of speech is not supported by the replication, hence the distinction may not be warranted. Furthermore, the failure to find a consistent verbal-then-motor response sequence may indicate that the two responses are independent events resulting from the same stimulus.

Thus there is conflicting evidence concerning the replicability of the findings cited by Luria in support of his stage model of the development of verbal regulation of nonverbal behaviour. However, for the studies which fail to replicate Luria's findings, the same flaw is repeated in all of them, i.e., a short interstimulus interval is programmed (1.5s or less). This is important because a lot of Luria's evidence relates to the effect of experimental manipulations on perseveration of responding. With short interstimulus intervals there is not much time in which subjects can perseverate. Hence any differences between age groups may be masked. Rondal's experiments used longer interstimulus intervals (4 to 6s), and the results largely supported Luria's stage theory.

Another problem with most of the studies is the limited age range of subjects, such that an examination of Luria's claims regarding Stage 1 responding is precluded.

A more basic limitation with the studies cited by Luria, and their replications, is that they examine the effect of instructed self-instructions on the nonverbal responding of children. Thus they do not explore the spontaneous use of self-instructions. However, a number of studies, which do not attempt to replicate Luria's experimental procedures, have examined the spontaneous use of self-verbalizations by children, while focussing on the first stage of Luria's model. These studies have attempted to clarify why language is not used to regulate behaviour during this period of development.

<u>Mediational deficiency hypothesis</u>

Reese (1962) attached the label "Mediational deficiency hypothesis" to the theory that there is a developmental stage during which children are verbal, but unable to use verbal responses to mediate nonverbal behaviour.

In support of the hypothesis, Reese cited research which examined whether children respond in a way which is consistent with a single unit S-R theory, or in a way which implies the operation of a mediational mechanism. Kendler and Kendler (1959) used a procedure in which subjects were required to choose one of two stimuli which differed on two dimensions (eg. size and colour), only one of which was relevant to making the correct choice. After training on this discrimination, the criterion for a correct response was changed. For a reversal shift, the same stimulus dimension was relevant, but the choice had to be reversed for the response to be correct (eg. if small stimuli were correct for the first discrimination, then large stimuli were correct for the second discrimination). For a nonreversal shift, the other stimulus dimension became relevant, and the dimension involved in the first discrimination became irrelevant (eg. correct choices for the second discrimination were based on the colour of the stimulus, regardless of its size). Kendler and Kendler proposed that if subjects respond according to direct S-R associations, then a nonreversal shift should be achieved more rapidly than a reversal shift. This is because the correct stimulus in a nonreversal shift is relatively neutral compared to the correct stimulus in a reversal shift which has been actively selected against in the prior discrimination. However, if subjects' responding is verbally mediated, the reverse is predicted. In this case the reversal shift should be easier because the subject is able to use the same mediating response, only changing the overt response. By comparison, for the nonreversal shift an entirely new mediating response would have to be acquired. Kendler and Kendler tested children aged 58 months to 78 months (4yrs 10mths - 6 yrs 6mths) using reversal and nonreversal shifts, and found that neither the single unit or mediational theory was confirmed. That is, there was not a significant difference in the speed of acquisition between subjects in the reversal shift condition and those in the nonreversal shift condition. However, when the subjects were divided into fast and slow learners, based on the number of trials taken to reach criterion performance in the training discrimination, an effect emerged. This was that fast learners responded in a way consistent with the mediational theory, while slow learners responded in a way which was consistent with the single unit theory. Thus, as a group, the subjects in this experiment may have been in a transitional stage between nonmediated and mediated responding.

In a second study Kendler, Kendler and Wells (1960) compared the performance of younger children (33 to 63 months; mean age 48.7 months or 4 years) on reversal and nonreversal shifts. Results showed that the reversal shift took significantly longer to acquire than the nonreversal shift, a pattern consistent with nonmediated responding. Thus while children of this age are clearly verbal, they do not appear to use verbal responses to mediate nonverbal responding. Kendler et al. (1960) noted that it was not uncommon for subjects in their study to simultaneously verbalize the correct response and make an incorrect response, with some children repeating this for a number of trials.

Given these results Kendler and Kendler (1962) concluded that the acquisition of verbal responding is insufficient for the development of verbal mediation of behaviour. Rather, further developmental changes are required to enable verbal responses to become integrated into nonverbal response chains.

Production deficiency hypothesis

There are two possible interpretations of the mediational deficiency hypothesis. One is that young children actually produce the verbal mediators, but they are not able to mediate responding with them. The second is that children at this stage of development are unable to produce appropriate verbal mediators.

Flavell, Beach and Chinsky (1966) called the latter theory the "Production deficiency hypothesis" and conducted an experiment to test it. They compared the performance of three age groups of children (5 to 6 years; 7 to 8 years; and 10 to 11 years) in a serial recall task. Subjects watched the experimenter point to three of seven pictures of objects, following which the spatial arrangement of the pictures was shuffled and the subjects were required (either immediately or after a 15s delay) to point to the same three objects in the same order. A trained observer recorded any speech emitted by the subject, including lip movements. Results showed a significant increase in spontaneous verbal production with age. Very few of the youngest group of subjects made any verbalizations. Thus the study indicated that young children may not produce verbal mediators to aid performance in recall tasks.

A similar procedure was used in another study to compare the validity of the production and mediation deficiency hypotheses (Moely, Olson, Halwes, & Flavell, 1969). Children in four age groups (5-6yrs, 6-7yrs, 8-9yrs, and 10-11yrs) again performed a recall task involving pictures of common objects which could be grouped into four categories. In the control condition, subjects were given two minutes to remember all the pictures, having been informed that they could move them around if they wished to. In the naming condition, the same procedure was followed, except that the experimenter named the four categories and indicated to subjects which pictures belonged in each category. In the teaching condition, subjects were instructed to sort the pictures into their categories, to label the categories, and to count the number of pictures in each category. Subjects were also instructed that recall would be enhanced by remembering the category labels and the pictures in each category. The pictures were then shuffled again prior to the actual recall task. Results showed little difference in spontaneous clustering of the pictures between the three youngest groups of subjects, but a sharp increase with the oldest group. The relation between age and recall showed the same pattern, with the only significant differences being between the oldest group of subjects and each of the younger groups. There was an interaction between age and experimental condition, such that for the two youngest groups the teaching condition resulted in more clustering than the naming condition, while for the 8 to 9 year-olds there was not a significant difference in the facilitative effect of these conditions. There was also a significant improvement in recall across conditions, with higher recall scores for the naming and teaching conditions.

These results suggest that, in recall tasks at least, the comparatively poor performance of younger children is associated with their failure to use a clustering strategy. Assuming that the clustering strategy requires the production of verbal labels for the stimulus categories, the mediation deficiency hypothesis would predict no improvement in recall even if there were an increase in the frequency of the verbal mediational response. However, when young children were trained to cluster, their performance improved. This finding then, supports the hypothesis that failure of young children to mediate performance verbally is due to a production deficiency, rather than a mediation deficiency.

The studies cited in support of the mediational and production deficiency hypotheses provide only indirect evidence regarding verbal responding, as there is no direct measure of the subjects' self-instructions. Rather, the effect of covert verbal responding is deduced from the nature of overt nonverbal responding. However, unlike the experiments reported by Luria, and their replications, the studies here do examine the spontaneous use of self-verbalizations. Despite limitations, they provide some support for the theory that verbal responding mediates nonverbal responding in older children, while for younger children there is a stage during which the two response systems are independent.

Comparison of Luria's model with the verbal control theory

These two models of the interaction of verbal and nonverbal behaviour, while being grounded in different experimental and theoretical paradigms, share a number of features. Both claim that the differences between animal and human behaviour arise because human behaviour is mediated by covert verbal rules. In support of this claim, both models have lead to experiments comparing performance of preverbal and verbal children on experimental tasks. Within both paradigms there has been evidence of a transitory stage in the development of verbal regulation, such that when children initially acquire speech, the verbal and nonverbal systems are not coordinated, and nonverbal behaviour is not verbally mediated. The evidence from both experimental traditions indicates that this transitional stage occurs before the age of 4 to 4.5 years.

However, despite the convergent evidence, proponents of the verbal control theory have failed to conclusively refute the epiphenomenal hypotheses. Recently a study was published which used both a temporal sequence analysis and a developmental framework to compare the verbal control and epiphenomenal positions.

1.7 A Study by Pouthas, Droit, Jacquet, and Wearden

Pouthas, Droit, Jacquet, and Wearden (1990) examined the relationship between verbal and nonverbal behaviour for children of 4.5 (n=18), 7 (n=20), and 11 (n=20) years of age on a task requiring temporal differentiation of button press duration. The task involved pressing a button on each of 40 discrete trials, with a

5.0s button press as the target duration. Minimal instructions outlined to subjects that they would have several tries to play with the button, and included a demonstration of the range of feedback for button presses. Verbal feedback was given at the end of each trial, and varied with the button press duration as follows (translated from French):

- for durations of $4.0 \leq x \leq 6.0$s: "very, very good"
- for durations of $2.5 \leq x < 4.0$s and $6.0 < x \leq 7.5$s: "moderately good"
- for durations of $x < 2.5$s or $x > 7.5$s: "not good at all".

For the two youngest groups of subjects, verbal feedback was accompanied by the brief presentation of a happy, serious, or sad clown face (corresponding to very very good, moderately good, and not good at all, respectively). After each trial the experimenter asked half of the subjects (probe condition) "What did you have to do to get very, very good?". Responses to the question were recorded by an observer. The other subjects (interview condition) were only interviewed at the end of the experimental session. For all subjects, trials began with the experimenter saying "You can play", and were followed by a 30s intertrial interval.

Results showed that performance tended to be better in the probe condition, compared to the interview condition, and that within the probe condition performance improved with age (no statistical analyses were presented). In the probe condition, there were eleven 11 year-olds, eleven 7 year-olds, and ten 4.5 year-olds. The number of subjects in each age group who emitted more than 20 successful[1] responses was 7, 4, and 3 respectively. Three 11 year-olds, six 7 year-olds, and five 4.5 year-olds emitted fewer than ten successful responses.

For the probe condition, verbal responses were coded according to a 13-category classification system (see Table 1), ranging from Category 1, representing no verbalization, to Categories 11-13 (the "timing categories") which represented increasingly specific verbalizations of timing contingencies. For the 11 year-olds there was a strong association between number of successful button press responses and number of timing verbalizations, but no such association was shown by the two younger groups with the exception of one 7 year-old (AU) who exhibited a high number of both. Apart from this one subject, no other 7 or 4.5 year-olds emitted any timing verbalizations. This failure to emit timing verbalizations was not secondary to a lower number of verbalizations, as there was very little difference between the age groups with respect to total number of verbalizations.

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[1]Successful responses were defined as button press durations within the range of 2.5 to 7.5 seconds.

Table 1.1
Description of verbalization categories used by Pouthas et al. (1990).

1. No verbalization.
2. No idea/don't know.
3. Repetition of consequence.
4. Verbalization without any relation to the task.
5. Press the button.
6. Manipulation of the button.
7. Localization of response on the button.
8. Response force.
9. Response sequences.
10. Repeated responses.
11. Response duration.
12. Limited response duration.
12+/-. Response duration longer/less than previous trial.
13. Chronometric counting.

For those 11 year-olds who emitted more than 20 successful presses an examination of temporal sequence revealed that for all but one subject (JU) the first timing verbalization preceded the first successful button press. Generally, there was a lag of several trials after the first timing verbalization before the first successful button press was emitted. For subject JU, the first successful button press was emitted on the first trial, and the first timing verbalization on the second trial.

There were eight 4.5 year-olds, nine 7 year-olds, and nine 11 year-olds in the interview condition. Three of the 4.5 year-olds emitted more than 20 successful button presses. Of these three, two gave timing verbalizations in the interview, while no other subjects in the group did. Two of the 7 year-olds responded successfully on more than 50% of the trials, and these were the only two subjects in this age group to give timing verbalizations in the interview. Of the 11 year-olds, four responded successfully on more than 20 trials, and three of these four subjects were the only 11 year-olds to emit timing verbalizations.

There seems, then, to be an inconsistency between the results in the probe and interview conditions. The data from the verbal probe condition show that for 11 year-olds only, there was a strong relationship between number of timing verbalizations and number of successful button press responses, with the first timing verbalization typically preceding the first successful button press. Such findings support the contention that in children of this age, nonverbal behaviour is mediated by verbal rules. By comparison, the data for the younger children are quite different, with only one subject emitting timing verbalizations at all. The absence of timing verbalizations is striking, particularly since some children in each age group emitted a large number of successful button press responses. This finding indicates that the 4.5 and 7 year-olds were not using verbal rules to mediate their timing behaviour in this task.

The failure of the 7 year-old subjects in the verbal probe condition to verbalize timing strategies is not consistent with the results of an earlier study by Pouthas and Jacquet (1987). This study compared the performance of 4.5 and 7 year-olds on DRL schedules, and found that most of the 7 year-olds, but only one of the 4.5 year-olds, verbalized a waiting strategy at the end of the experiment. This was despite the fact that almost all subjects acquired the temporal discrimination on a DRL5sec schedule.

However, as Pouthas et al.(1990) point out, the failure of younger subjects to vocalize timing strategies does not preclude the possibility that these subjects used verbal rules which the probes failed to elicit. In this respect, the data from the interview condition seem at odds with findings from the verbal probe condition. Namely, results from the interview condition showed that across all ages, the few subjects who were successful at the button press task related timing strategies after the experimental session. Thus it appears there may be an association between successful button press responses and statement of a timing strategy for all ages, although the number of subjects in this condition who responded successfully on 20 or more trials is too low to permit any firm conclusions. Pouthas et al. did not discuss this apparent discrepancy, and interpreted their findings as supporting the theory of a period of dissociation between verbal and nonverbal behaviour, following which nonverbal behaviour is mediated by verbal rules.

However, the conclusions regarding the independence of verbal and nonverbal responding in the two younger groups of subjects must be regarded as somewhat tentative. Furthermore, while data for the older subjects may appear to support the verbal control theory, the evidence is still correlational, relying on the temporal sequence and developmental strategies.

The aim of the current study was to more closely examine the claim by Pouthas et al. that younger subjects do not use verbal rules to mediate their timing responses, and to further explore the use of the verbal interference technique in distinguishing between the verbal control and epiphenomenal theories.

1.8. Rationale for the Current Study

Summary

Despite convergent evidence from experiments conducted in the operant tradition and those cited in support of Luria's stage theory, proponents of the verbal control theory have failed to conclusively refute the epiphenomenal hypotheses. This is largely because of limitations on the experimental approaches used to date.

The major limitation with the studies cited by Luria in support of the stage model is that they examine the effect of instructed self-instructions, and do not throw light on the spontaneous use of self-verbalizations by children. Furthermore, replications of the studies have have failed to consistently support the original findings. Later studies examining the mediational and production deficiency hypotheses do look at the spontaneous use of self-verbalizations, but only indirectly. Thus the action of self-verbalizations is inferred from subjects' nonverbal behaviour, and is not independently verified.

While a number of experimental approaches have been used within the operant research tradition, none has been able to provide conclusive support for either the verbal control theory or the epiphenomenal hypotheses. Much of the evidence cited in support of the verbal control theory is correlational in nature and hence ambiguous. For example, correlations between nonverbal responding and post-experimental verbal report are predicted by both theoretical positions and fail to isolate causal factors. Developmental studies are also correlational in nature, and fail to isolate verbal behaviour as the causal variable for maturational changes in nonverbal responding. The examination of the time-course of changes in verbal and nonverbal behaviour, is another correlational technique. However, a demonstration that changes to verbal behaviour consistently precede changes to nonverbal behaviour would present a greater challenge to epiphenomenal hypotheses.

Studies examining the effect of instructions on human behaviour, enable some control over verbal behaviour, but only that of the experimenter, not the subject. As with the studies cited by Luria, the manipulation of experimenter-provided instructions provides no insight into the spontaneous use of self-instructions.

Interference techniques potentially have the most power to distinguish between the two theoretical positions than any of the other experimental strategies as they attempt to directly manipulate the covert verbal behaviour of the subject and examine the resulting effect on nonverbal behaviour. The function of indirect interference strategies is to make covert verbalizations redundant. A limitation with these strategies is that they rely on post-experimental report to gauge if this has been achieved. Direct interference strategies attempt to disrupt and prevent covert verbalizations by requiring subjects to carry out a competing concurrent verbal task. To date only a few studies have used this strategy, and all have failed to control for the effect of divided attention. Rather, they have used control conditions in which the subjects do not engage in a concurrent task at all. This fails to isolate the effect of the verbal nature of the interference. Thus a number of factors, such as reduced attention or fatigue, could be postulated to account for the effects observed. What is required is a control condition in which subjects engage in a concurrent task, which involves vocalization but not verbalization. In this way, disruption due to the verbal nature of the concurrent task can be isolated.

The current study

This study was a replication, with modifications, of the experiment by Pouthas, Droit, Jacquet, and Wearden (1990). While the basic button press task remained the same, subjects were also required to carry out a concurrent task. In the verbal condition, the concurrent task was to verbally label aurally presented words as either numbers or names, while in the nonverbal condition the concurrent task was to shadow musical notes.

There are two purposes to the modifications made to Pouthas et al.'s study:

- to explore the use of a noncorrelational technique (verbal interference), within a developmental context, as a strategy for comparing the verbal control and epiphenomenal theories
- to examine whether young children may have verbal rules that control behaviour, but which are not elicited by verbal probes.

A problem with the experiment by Pouthas et al. was that the two strategies used to distinguish between verbal control and epiphenomenality- developmental comparison and temporal sequence analysis- both resulted in evidence, which while favouring the verbal control theory, was correlational in nature. Verbal interference is not a correlational technique. However, in the few studies which have employed it, the effect of interfering with verbal activity *per se* has not been separated from the effect on behaviour of performing a concurrent task in general. In this study, shadowing sung notes is used as a control for divided attention. This task was chosen because it controls for the effect of vocalization on performance, while remaining nonverbal.

A second advantage of using a verbal interference task is that it has the potential to identify whether younger children use verbal rules which verbal probes fail to elicit. Pouthas et al. concluded that older children (11 year-olds) used verbal behaviour to mediate nonverbal responding on the button press task, while younger children did not. If this is so, then for the 11 year-olds the verbal concurrent task should interfere with performance on the button press task more than the nonverbal task. With younger children (4.5 and 7 year-olds), the interference resulting from the verbal task should be less than it is for the older children, and should approximate the level of interference from the nonverbal task. If, however, the younger children do use covert verbal rules which they fail to vocalize in response to questionnaires and probes, their performance should be poorer with the verbal interference condition than in the nonverbal interference condition.

2. METHOD

2.1 Subjects

Sixty-three children participated in the study, with 6 failing to complete the experimental session due to refusal to continue (n=4) or distress(n=2). The remaining 57 subjects comprised sixteen (10 female and 6 male) 4.5 year-olds (range = 51-57 months, mean age = 4 years 6.4 months); twenty (9 female and 11 male) 7-8 year-olds (range 84-97 months, mean age= 7 years 5 months); and twenty-one (17 females and 4 males) 10-12 year-olds (range = 130-144 months, mean age = 11 years 6.9 months).[1] All of the 4.5 year-olds attended a local kindergarten while of the two older age groups, twelve 7 year-olds and thirteen 11 year-olds were pupils at a primary school in the same locality. The remaining 16 children were recruited through acquaintances.

2.2 Settings

The experiment was conducted in a number of settings. These included an office at the kindergarten (Mairehau Kindergarten), two offices at the primary school (Mairehau Primary School), two home offices, and an office at Canterbury University. The arrangement of equipment was the same in all offices, and is depicted in Figure 2.1.

Mairehau Primary School and Mairehau Kindergarten are both public (i.e. state-funded) institutions, and draw pupils from a catchment area representative of a typical Christchurch suburban area.

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[1] The 2 older age groups will be referred to as 7 year-olds and 11 year-olds throughout the rest of the thesis. Only three subjects (one 8 year-old, one 10 year-old, and one 12 year-old fall outside the strict definition of these labels, and even then they fall just outside the age boundaries.

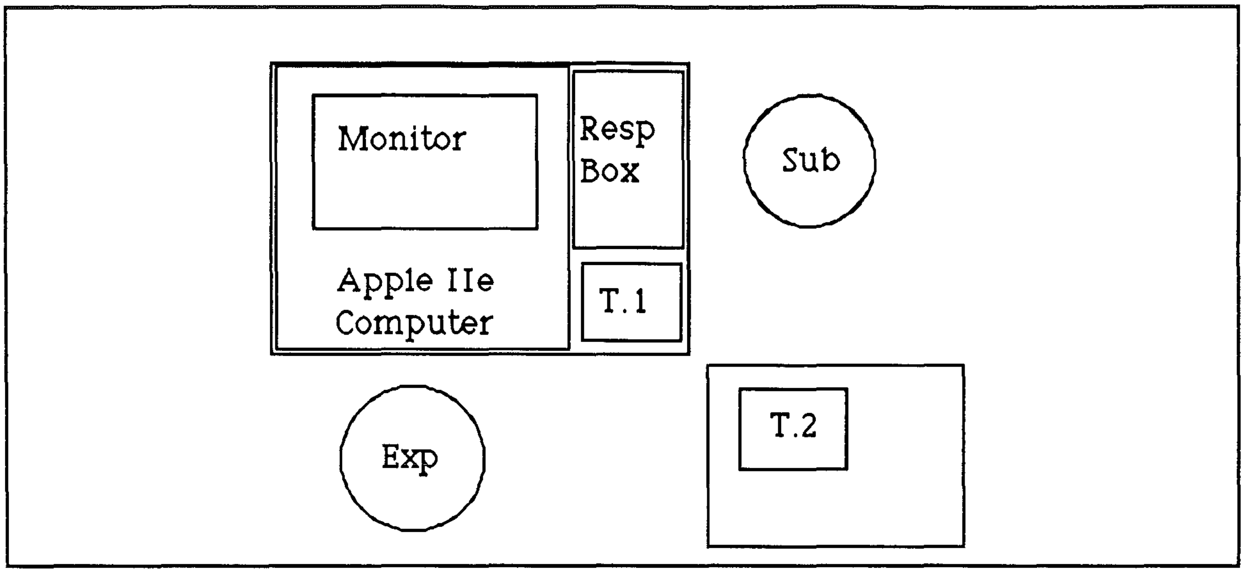


Fig. 2.1. Overhead view of equipment and seating layout.
Resp Box= Response box; Sub= Subject; Exp= Experimenter
T.1= Tape recorder for playing interference task cassettes
T.2= Tape recorder for making audio recording of session

2.3 Apparatus and Materials

The equipment consisted of an Apple IIe computer, monochrome monitor, metal response box, two CLASSETTE 148B ATC Listening Centre tape recorders, and feedback cards.

Subjects sat at a table facing the response box (31.5 cm wide by 20.5 cm high by 22.5 cm deep). A BRS Forringer Primate key (4cm diameter) made of translucent perspex was recessed (8mm) into the front panel of the box,14cm from the left front edge and 8.5 cm from the bottom edge. It was connected to the games port of the computer, and could be illuminated from behind with green light supplied by a 24 volt DC bulb. The key required a force in excess of 100 grams (1 Newton) to depress through a distance of 2mm. When the key lit up with green light, pressing it illuminated a small (1.4 cm diameter) 24 volt DC red light situated 2.5cm directly above the key. The computer controlled the operation of the red and green lights through a Life Sciences Associates Relay Interface Board, and timed the intertrial interval, and the duration of key illumination and key press, using a SMT NO-SLOT CLOCK. The computer programme was written in Applesoft Basic, and is reproduced in Appendix A.

The experimenter sat facing the monitor which was positioned on top of the computer, side-on to the subject and angled slightly in the opposite direction, so that there was no chance of the subject seeing the information on screen.

Three coloured photographs of clown faces were mounted on individual cards (13cm by 18 cm) which were then hinged by the bottom edge to the back edge of a large piece of cardboard which sat flat on top of the response box. The cards were attached so that the clown faces did not show, unless a card was lifted by pulling on a loop of sticky tape at the back. The original clown faces were made of coloured card (blue, white, red, yellow, and black) and differed only in mouth shape- one had a smiling, one a neutral, and one a sad mouth shape.

Stimuli for the two interference conditions were presented by audio tapes played on a taperecorder, which sat to the left of the response box. One 45 minute tape was constructed for each condition, so that all subjects within a condition received the same order of stimulus presentation. Stimuli on both tapes were recorded in random order. The stimuli were as follows:

a) Verbal Interference (VI) Condition- Ann; Sue; Faye; Jane; Mark; Paul; Bob; Tom; One; Two; Three; Four; Five; Six; Eight; Nine

b) Nonverbal Interference (NI) Condition- the following notes were sung as "la"- middle C; C#; D; D#; E; F; F#; G

For both tapes, all stimuli were prerecorded in the same female voice, and were then edited together so that the stimulus duration was 1.0 s and the stimuli were spaced randomly at 3.0 and 5.5 s intervals.

An audio recording was made of the experimental session using the second tape recorder, placed on a table to the left of the subject.

Subjects received a small, noncontingent, gift at the completion of the experimental session. The kindergarten children were invited to choose one of an assortment of stickers; the children at the primary school received a certificate of participation; and the remaining children were allowed to choose one of a variety of small gifts such as coloured pencils and stickers.

2.4 Procedure [1]

Within each age group, subjects were grouped according to gender, and then, randomly, were assigned to one of the two experimental conditions (VI or NI). The assignment of subjects is described in Table 2.1.

Table 2.1
Number of subjects, grouped for age and gender, in each experimental condition

Age		**Experimental Condition**	
		VI	NI
4.5 yrs	Female	5	5
	Male	3	3
7 yrs	Female	4	5
	Male	6	5
11 yrs	Female	8	9
	Male	2	2

Each subject was seen individually for one session, which lasted approximately 40 minutes. Prior to beginning the session, the experimenter checked to see if the child was wearing a watch. If so, the child was asked to leave the watch outside the room, with the explanation that the watch could cause interference with the equipment. There was no indication that children were suspicious of this explanation.

A. INTRODUCING THE INTERFERENCE TASK

Verbal Interference Condition

After the child sat down in front of the response box, the following instructions were given:

Let's play a word game. In this game I'm going to play you some words, one at a time. Some of the words are children's names, and some of the words are numbers. After you hear a word, you job is to tell me if it is a number or a name. Let's try a word.

[1] The procedure was refined following two pilot investigations which are described in Appendix B.

The experimenter then played the first word on the tape, pausing the recorder after this word. Five seconds were allowed for the child to reply.

If the child responded correctly, the experimenter said:

Very good. Let's try another one.

If the child responded incorrectly , the experimenter said:

No- you should say name/number because .... is a name/number. Let's try another one.

(The blanks were filled in with original stimulus, and name or number was stated as appropriate).

If the child gave no answer within 5 seconds, the experimenter said:

After you hear ...., you say name/number because .... is a name/number. Let's try another one.

Stimuli were presented individually in this way until three consecutive correct responses were made. The following instructions were then given:

Now let's try some more names and numbers. This time I won't stop the tape in between them. Remember, after you hear a word, you tell me if the word is a name or a number.

Practice continued, without stopping the tape between stimuli, until the subject made three consecutive correct responses, including at least one name and one number.

Nonverbal Interference Condition

Once the child was seated the following instructions were given:

Let's play a singing game. In this game I'm going to play you some notes, one at a time. After you hear a note, your job is to sing the note. You sing the note just as it sounds. Let's try a note.

The experimenter then played the first note on the tape, pausing the recorder after this note. Five seconds were allowed for the child to reply.

If the child responded correctly, the experimenter said:

Very good. Let's try another one.

If the child responded incorrectly, the experimenter said:

No- after you hear ...., you should sing ....

Let's try another one.

(The experimenter sang the appropriate note in the spaces left blank).

If the child gave no answer within 5 seconds, the experimenter said:

After you hear ...., you sing .... Let's try another one.

The criteria for a correct response were very broad- any reproduction of a sung "la" was accepted. As with the VI condition, stimuli were presented individually until three consecutive correct responses were made. The following instructions were then given:

Now let's try some more notes. This time I won't stop the tape in between them. Remember, after you hear a note, you sing it just the way it sounds.

Practice continued, without stopping the tape between stimuli, until the subject made three consecutive correct responses.

B. INTRODUCING THE BUTTON PRESS TASK

Once the subject reached criterion performance on the interference task, the following instructions were given (inside the brackets, instructions for the VI condition will precede those for the NI condition):

You're (telling the names and numbers apart/singing the notes) really well. Now we're going to play two games. One of the games is to (say whether the words are names or numbers/ sing the notes) just as you've been doing. The other is to learn to play with this button.

(Experimenter reached over and pointed to the response key.)

You watch what happens to the button. (A practice trial was started on the computer, and after 15s the button lit up with the green light).

What's happened to the button?

When the button lights up with the green light, that means you can try and play with it. You will be able to try lots of times.

When you have finished your try the clown will tell you if it was very, very good (experimenter showed smiling clown); **if it was okay** (experimenter showed neutral clown); **or if it was not good** (experimenter showed sad clown).

Now remember, you are going to play two games at once. The

(word/singing) game, and the button game. We'll start off with the (word/singing) game, and when the button goes green you can play with the button, but keep playing the (word/singing) game at the same time. Let's have a practice turn.

This practice trial was run without giving the verbal or clown face feedback at the end. If the subject failed to perform one of the two tasks, the trial was repeated after the following instruction:

Remember, now we're playing two games at once. When the button lights up, play with the button, but don't stop playing the singing game. Let's have another practice turn.

Once one practice trial was completed in which there was some attempt to play with the button and the interference task was performed, the subject had some more practice trials in which there was instructed exposure to the reinforcement contingency. The target response was a button press of 5 seconds duration. The trials were introduced with the following instructions:

Now let's have another practice turn. This time, keep playing the (word/singing) game, but when the button lights up you press the button and hold it in, and I'll tell you when to take your finger off to make it very, very good.

The experimenter timed the button press with a concealed watch, and told the subject to let go of the button at 5 seconds. The subject then received "very, very good" verbal feedback, accompanied by the smiling clown face. This practice trial was repeated until the subject had performed two correct trials. If the subject failed to press the button for 5 seconds, no feedback was given, and the trial was repeated.

C. EXPERIMENTAL SESSION

Once the subject attained criterion performance on the practice trials, the experimental trials were introduced with the following instructions:

Now you can have lots of tries by yourself. Remember to play with the button when it lights up, but don't stop playing the (word/singing) game. The clown will tell you how well you are playing with the button.

The session consisted of 30 discrete trials. Trials began with 15s presentation of the interference task. The key was then illuminated with green light, and the button press duration timed and recorded by the computer. For all subjects, feedback for button presses was as follows:

- durations of 4.0 to 6.0s- "very, very good" and smiling clown
- durations of 2.5 to 4.0s and 6.0 to 7.5s - "okay" and neutral clown
- durations less than 2.5s or more than 7.5s - "not good" and sad clown.

If the duration of a button press exceeded 10s, the green key light went out and feedback was given. The computer monitor displayed the button press duration to the experimenter at the end of a trial, and instructed the experimenter as to the appropriate feedback.

If the subject failed to press the key within 10s of its illumination, the green light went out, the trial was stopped, "not good" feedback was given, and the child was then instructed:

Remember to play with the button when it turns green.

If the subject failed to perform the interference task while pressing the button, the trial was stopped, no feedback for the button press was given, and the child was instructed:

Remember, now we're playing two games at once. When the button turns green, play with the button, but don't stop playing the (word/singing) game.

The trial was then repeated- that is, the abandoned trial did not count towards the total of 30 trials for the session.

When a button press was completed, the interference task was stopped and the subject asked:

What do you have to do to get very, very good?

Subjects were allowed 30s to produce their response. Following this 30s, the next trial began with the onset of the interference task, and the instruction:

Let's have another turn.

D. RECORDING DATA

Button press duration was recorded by the computer and every session was audiotaped to record the subjects' responses to the probe question. However, both button press duration and subjects' responses were also manually recorded by the experimenter during the session. The experimenter used a clipboard and concealed the written record from the subject.

E. ENCODING RESPONSES TO THE VERBAL PROBE

Each response was classified as belonging to one of the 15 response categories described in Table 2.2 (adapted from Pouthas et al., 1990). Encoding was completed after the session by the experimenter.

A reliability check was performed on response encoding for 10 randomly chosen subjects (three 4.5 year-olds; four 7 year-olds; three 11 year-olds). An observer, who had no involvement in the data collection, transcribed the subjects' responses from audiotape and encoded them.

Table 2.2
Description of, and examples from, categories used for encoding subjects' verbalizations. (Adapted from Pouthas et al., 1990.)

1. No verbalization
2. No idea/ don't know
3. Description of consequence eg. "you have to get that clown"; "you get lollies"; " I'm not getting good"
4. Verbalization which is not related to either the button press or the concurrent tasks eg. " colour in"; " help each other"
5. Verbalization related to button press or concurrent task which does not incorporate a specific behavioural strategy for either task eg. "try harder"; "play with the button"; "practise"; " be good"
6. Verbalization related to concurrent task, with no reference to button press task eg. "sing better"
7. Verbalization of a specific strategy related to the button, but not including pressing eg. " don't press the button"; "look at the button"
8. Press the button eg. "push the button"; "push the button when it goes green"
9. Localization of button press response eg. " press the button right in the centre"
10. Force of button press response eg. "press the button softer"; "push the button in hard"
11. Repeated button press responses/ specified number of button press responses eg. "keep pushing it in and out"
12. Latency of button press response eg. "I could press the button as soon as it turns green"
13. Duration of button press response eg. "don't let go of the button"; "keep your finger on the button"
14. Limited button press response duration or duration longer/shorter than on previous trial eg. " I just keep my finger on the button until about 5 seconds"; "once the button comes on, press it and then take your finger off"; "keep your hand on the button longer"
15. Chronometric counting eg. "remember to put your finger on the button and count to 10"

3. RESULTS

3.1 Button Press Response

A wide variation in button press duration was recorded both between and within subjects. Appendix C contains a line graph for each subject showing response duration across the thirty trials. As can be seen from these line graphs, apart from those subjects who maintained very long or very short response durations, few subjects achieved stability in responding.

Four patterns of responding are apparent in these graphs, and may be characterised by the response typology described in Table 3.1.

Table 3.1

Description of typologies for button press response patterns

Learners- Responding shows stability within range of successful response durations by the end of the thirty trials.

Trackers- Responding traverses the range of successful button press durations until unsuccessful responses are emitted. Response duration then traverses back in the opposite direction.

Oscillators- Response duration oscillates between very short and very long responses.

Extremists- Response duration remains very short or very long.

The four types can be divided into two subgroups according to whether there was any sign of task acquisition or not. Learners and trackers showed some acquisition, with learners displaying more stable responding. Oscillators and extremists failed to show any acquisition of the task, and persisted in maintaining unsuccessful response strategies.

Each subject was categorized according to the type of response pattern displayed. The frequency distribution of response types is shown in Table 3.2. A check for reliability of categorization revealed an agreement rate of 81% between observers.

As can be seen from Table 3.2, twenty-three (10 oscillators, and 13 extremists) subjects failed to display any sign of task acquisition. These subjects were evenly distributed across the three age groups- with 7 in the 4.5 year-old group; and 8 subjects in each of the two older age groups. These represent proportions of total group number of 0.44, 0.4, and 0.38 respectively.

Table 3.2
Number of subjects displaying each type of response pattern.
Frequency is shown by age and experimental condition.

Age	Condition	Learner	Tracker	Oscillator	Extremist
4.5 yrs	VI	0	5	2	1
	NI	0	4	2	2
7 yrs	VI	3	5	1	1
	NI	0	4	2	4
11 yrs	VI	3	4	0	3
	NI	1	5	3	2
Total Number of Subjects		**7**	**27**	**10**	**13**

Thirty-four subjects, namely 27 trackers and 7 learners, showed some task acquisition.

The number of trackers in each age group was equal at nine, representing proportions of total group number of 0.56, 0.45, and 0.43 for the 4.5-, 7-, and 11-year-olds respectively. Moreover, within each age group the number of trackers within the VI and NI conditions were very similar.

There were only 7 learners in total, with no learners in the 4.5 year-old age group, 3 in the 7 year-olds, and 4 in the 11 year-olds. Collapsing across the 7- and 11-year age groups revealed that only 1 learner was in the NI condition, while 6 were in the VI condition. However, expected cell frequencies are too low (< 5) for some cells to permit a Chi-square analysis. A comparison of numbers of learners and trackers vs oscillators and extremists across the two conditions failed to reach significance ($X^2= 3.22$, $df= 1$, $n= 41$, $p> .05$).

As learners show a more stable response pattern in the range of successful response durations than trackers, it might be expected that learning is a more advanced stage of acquisition that follows tracking. Thus if the first, second, and third ten trials were categorised independently, one might expect to find that learning follows earlier tracking. This is in fact the case for 5 of the 7 learners. Of the other two, one (103) displayed stable responding throughout the session, and one (707) learnt in the final few trials of the session, having failed to show any sign of acquisition in the first 20 trials.

Given the distribution of types of button press response pattern, was there any effect of age, condition, or trial order on response duration? A 3(age) X 2(condition) X 6 (trial blocks) ANOVA, with repeated measures on the trial factor, was conducted. Trials were grouped sequentially into 6 blocks of 5, with the mean button press duration entered for each block. The analysis revealed no significant effects for age ($F(2, 51) = 1.34, p>.05$); condition ($F(1, 51) = 0.01, p>.05$); age by condition ($F(2, 51)= 0.353, p> .05$); trial order ($F(5, 255) = 1.363, p > .05$); age by trial order ($F(10, 255) = 0.974, p> .05$); condition by trial order ($F(5, 255) = 0.747, p> .05$); and age by condition by trial order ($F(10, 255) = 1.08, p> .05$). However, one problem with blocking the trials was that due to the often extreme within subject variation in response duration, frequently the average response duration for a block of trials did not resemble any of the actual response durations. The ANOVA was repeated, but this time with ten repeated measures on the trial factor, and the last 10 responses for each subject were entered into the analysis. This analysis also failed to reveal any significant main effects or interactions (at $p< .05$). Hence neither age, experimental condition, trial order, or any interaction of these factors had a significant effect on button press duration.

A more meaningful comparison may, however, be to compare number of successful button press responses (where "successful" button presses are those lying within the range of 2.5-7.5s), as with button press duration, successful responses lie in the middle of the range of values. A comparison of mean numbers of successful responses by age and experimental condition is depicted in Figure 3.1.

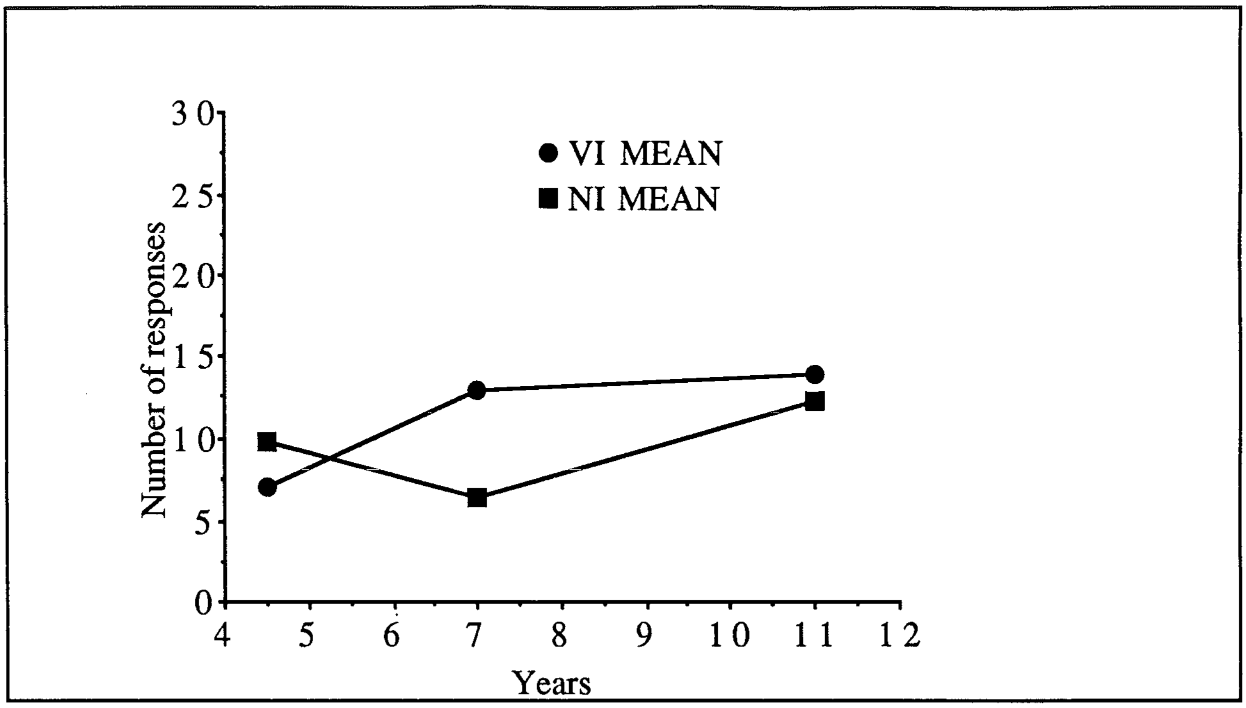


Fig. 3.1. Mean numbers of successful button press responses shown by age for each of the two experimental conditions (VI = verbal interference; NI = nonverbal interference).

While there appears to be an increase in mean number of successful responses with increasing age, this effect failed to reach significance ($F(2, 51) = 1.489$, $p > .05$). With respect to the two interference conditions, there does not appear to be a main effect, and this was confirmed by ANOVA ($F(1, 51) = .624$, $p > .05$). The graph indicates, however, that there could be an interaction effect, such that within the 7 year-old age group, subjects in the VI condition performed better on the button press task than subjects in the NI condition. However, ANOVA revealed that this effect was not significant ($F(2, 51) = 1.414$, $p > .05$).

Thus analysis of variance of button press response, using both button press duration and number of successful of responses as the dependent measure, revealed no significant effects from age, experimental condition, trial order, or any interaction of these factors.

3.2 Verbal Responses

The reliability check for the encoding of verbalizations revealed an agreement rate of 92% between the experimenter's and observer's categorization of responses.

A comparison of total number of responses to the verbal probe (verbal productivity) revealed no significant difference across ages ($F(2, 51) = 2.178$, $p > .05$). The mean number of responses per subject in order of increasing age was 28.1, 25.3, and 29.1 respectively. Nor was there a main effect for experimental condition on verbal productivity ($F(1, 51) = >008$, $p>.05$), nor a significant interaction between age and condition ($F(2, 51) = .524$, $p > .05$). Thus any differences between age groups, or experimental conditions, with respect to verbal responses can not be attributed to differences in verbal productivity.

The mean number of responses in each verbalization category is shown by age group in Figure 3.2. Timing verbalizations are those in categories 13 (button press duration), 14 (limited button press duration), and 15 (chronometric counting). In the youngest age group, only one timing verbalization was made (category 13). Thus no 4.5 year-olds responded with formulations of limited response duration or counting. In the verbal category distributions of the 7- and 11-year-olds, there are few verbalizations in category 15- that is, very few subjects related counting strategies. Counting strategies were related by one 7 year-old (715, n=4) and two 11 year-olds (109, n=1;112, n=12). Among the three timing categories, most responses in both of the older age groups fell into category 14, which encompasses those verbalizations relating to limited response duration. Thus there is a strong trend towards more timing verbalizations in the older age groups. A 3 (age) X 2 (condition) ANOVA confirmed the significant effect of age on number of timing responses ($F(2,51)= 6.89$, $p< .01$). An a posteriori Tukey test of means confirmed that the 4.5 year-olds made significantly fewer timing verbalizations than the 7 year-olds ($p < .05$) and the 11 year-olds ($p< .01$).

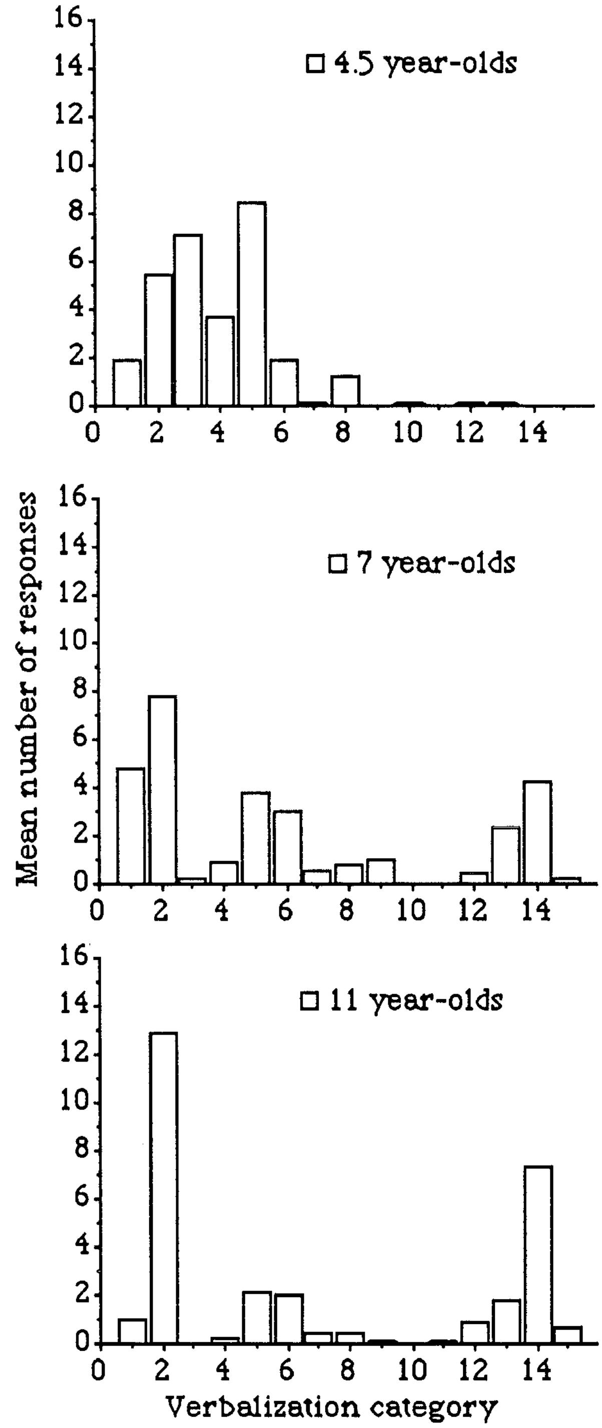


Fig. 3.2. Mean number of responses in each verbalization category, shown by age group.

With respect to verbalizations which were not related to response duration, there is a noticeable trend to fewer responses in Categories 3 (repetition of consequence),4 (unrelated verbalizations), and 5 (nonspecific responses) with increasing age. The youngest children made a lot of responses in Category 3. By comparison very few responses of this nature were made by subjects in the two older age groups. There is also a noticeable decline in task-irrelevant (category 4), and nonspecific responses (category 5) with increasing age. Category 5 verbalizations (eg. "You have to try") were the modal group for the 4.5 year-olds. In each age group there is a peppering of responses across categories 6-12, with responses in category 6 (related to concurrent task) being more frequent than responses in any other of these categories for all age groups.

There is a trend in the 7- and 11-year-old age groups for responses which are not related to response duration to take the form of "I don't know" (category 2)- which was the modal response category for both groups.The trend for non-timing verbalizations to take this form is stronger for 11 year-olds than it is for 7 year-olds.

Thus in general, the 7- and 11 year-olds made a significant number of timing verbalizations, while only one instance of a timing verbalization occurred with the 4.5 year-old subjects. Nonspecific verbalizations constituted the modal response group for the 4.5 year-olds, while for the two older age groups the modal response was of the form "I don't know." Overall, the 11 year-olds made fewer responses in other non-timing related categories than the 7- or 4.5-year-olds.

Figure 3.3 shows the average number of responses in each verbalization category by age and experimental condition. In general the data are too scattered to show any major trends. Analysis of variance revealed no main effect for condition on number of timing verbalizations ($F(1, 52) = .531$, $p > .05$), nor any interaction between age and condition ($F(2, 51) = .54$, $p > .05$).

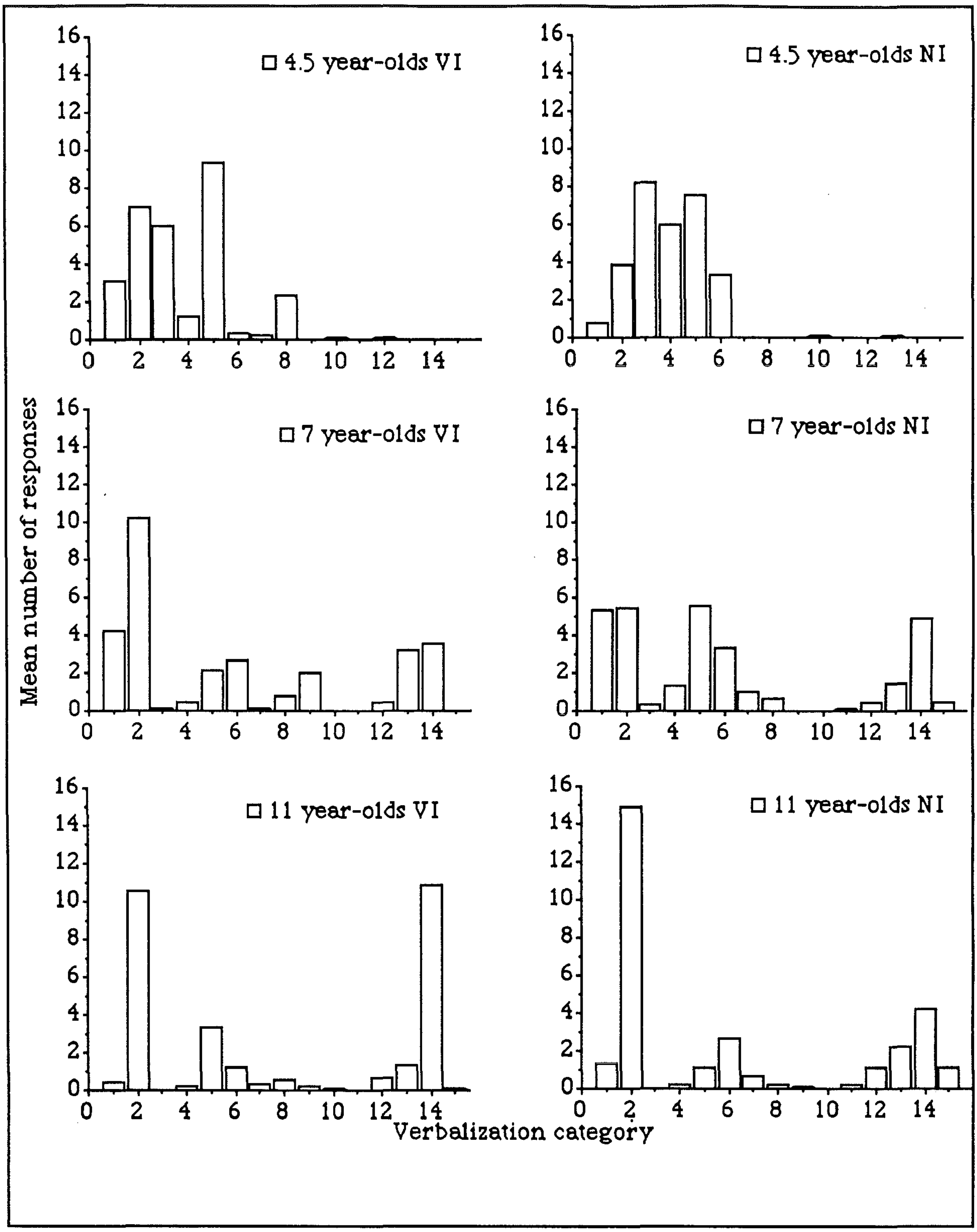


Fig. 3.3. Mean number of responses in each verbalization category by age and experimental condition.

3.3 Number of Timing Verbalizations vs Number of Successful Button Presses

With respect to the issue of verbal control, the relationship between timing verbalizations and successful button press responses is of interest. This relationship is expressed graphically in Figure 3.4, which shows scattergrams of number of successful button presses vs number of timing responses for each age group. Clearly, since only one instance of a timing response was expressed, there is no significant relationship between the two variables in the case of the youngest group of subjects ($r= -.30$, $n=16$, $p> .05$). A correlation coefficient can not be calculated for the 4.5 year-old VI group as no timing verbalizations were emitted by these subjects, but the coefficient for the NI group is not significantly different from zero ($r= -.43$, $n= 8$, $p> .05$). By comparison, there is a significant correlation between number of successful button presses and number of timing verbalizations in both the 7 year-old ($r=.66$, $n= 20$, $p< .01$) and 11 year-old ($r=.73$, $n= 21$, $p<.001$) groups. The difference between the coefficients for the two older age groups is not significant ($z= .402$). Within the 7 year-old age group, the correlation is significant for both the VI condition ($r= .73$, $n= 10$, $p<.05$) and the NI condition ($r= .75$, $n= 10$, $p < .05$), but the difference between them is not significant ($z=.08$). Within the 11 year-old age group, the correlation is also significant for both interference conditions (VI- $r=.76$, $n= 10$, $p< .05$; NI- $r= .71$, $n= 11$, $p< .05$), and the difference between the two coefficients is not significant ($z= .23$).

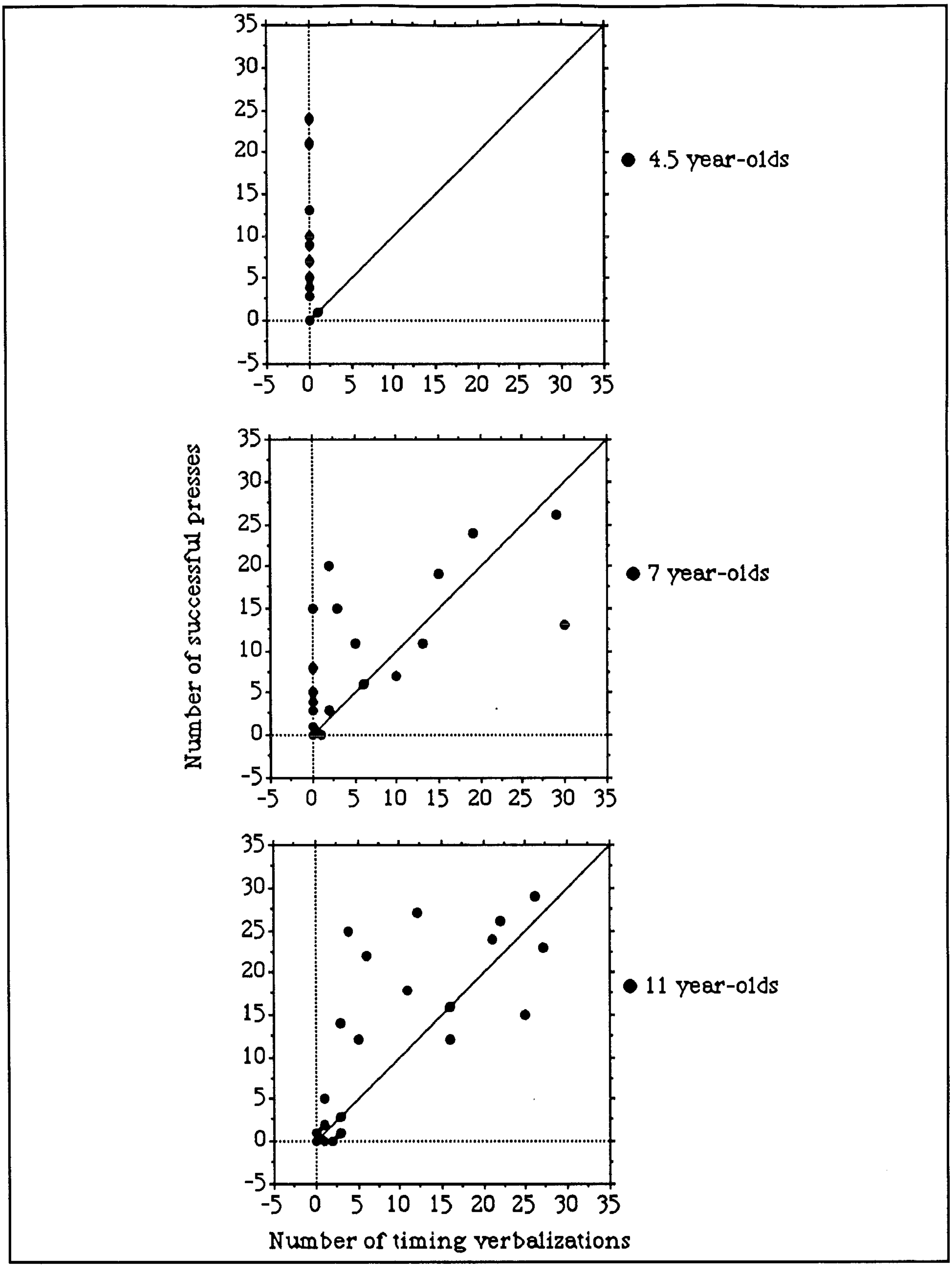


Fig. 3.4. Number of successful button presses versus number of timing verbalizations, shown by age group. The solid line depicts perfect matching.

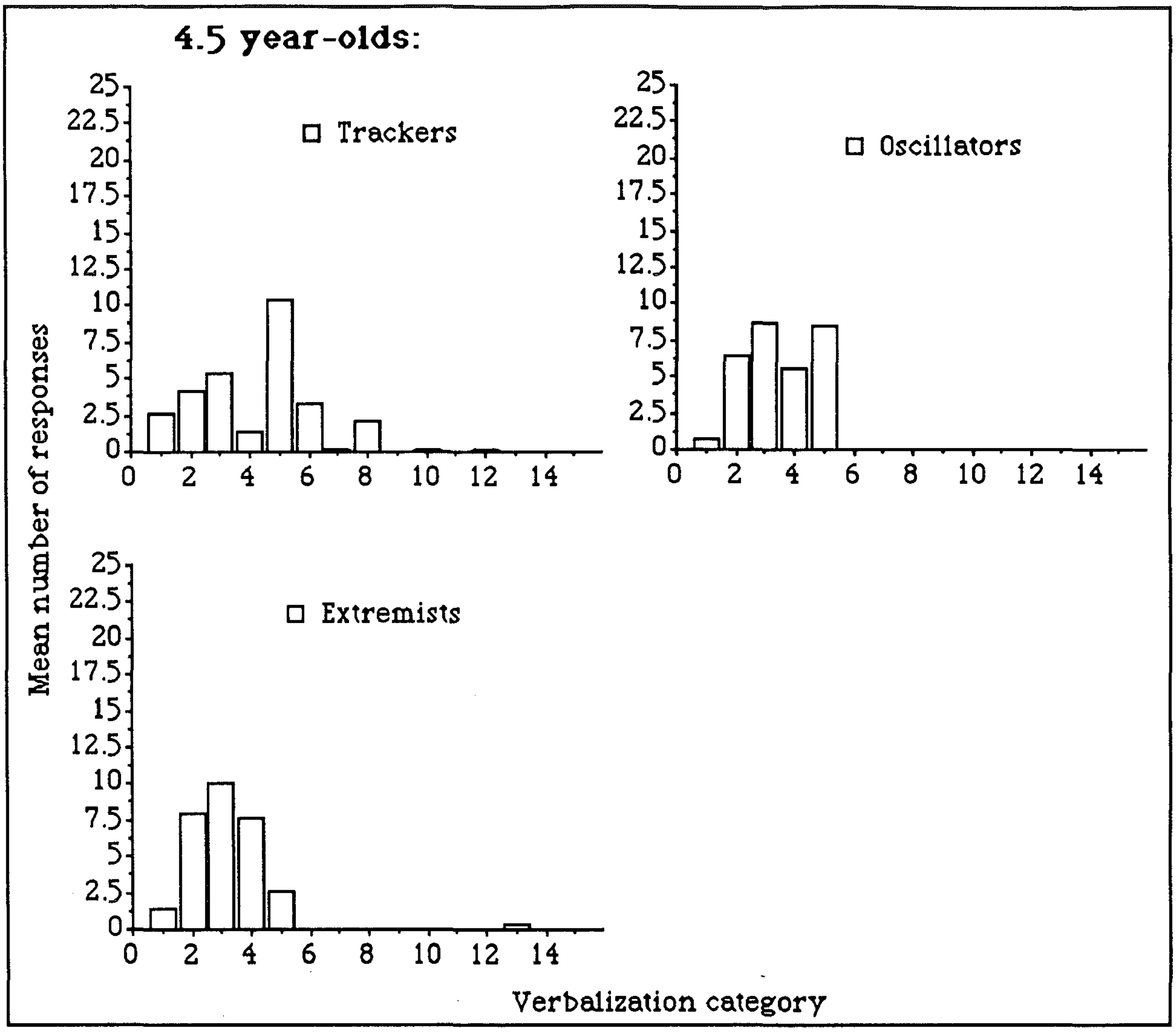


Fig.3.5. Mean number of responses in each verbalization category, shown by response typology, for each age group. Figure is continued over page...

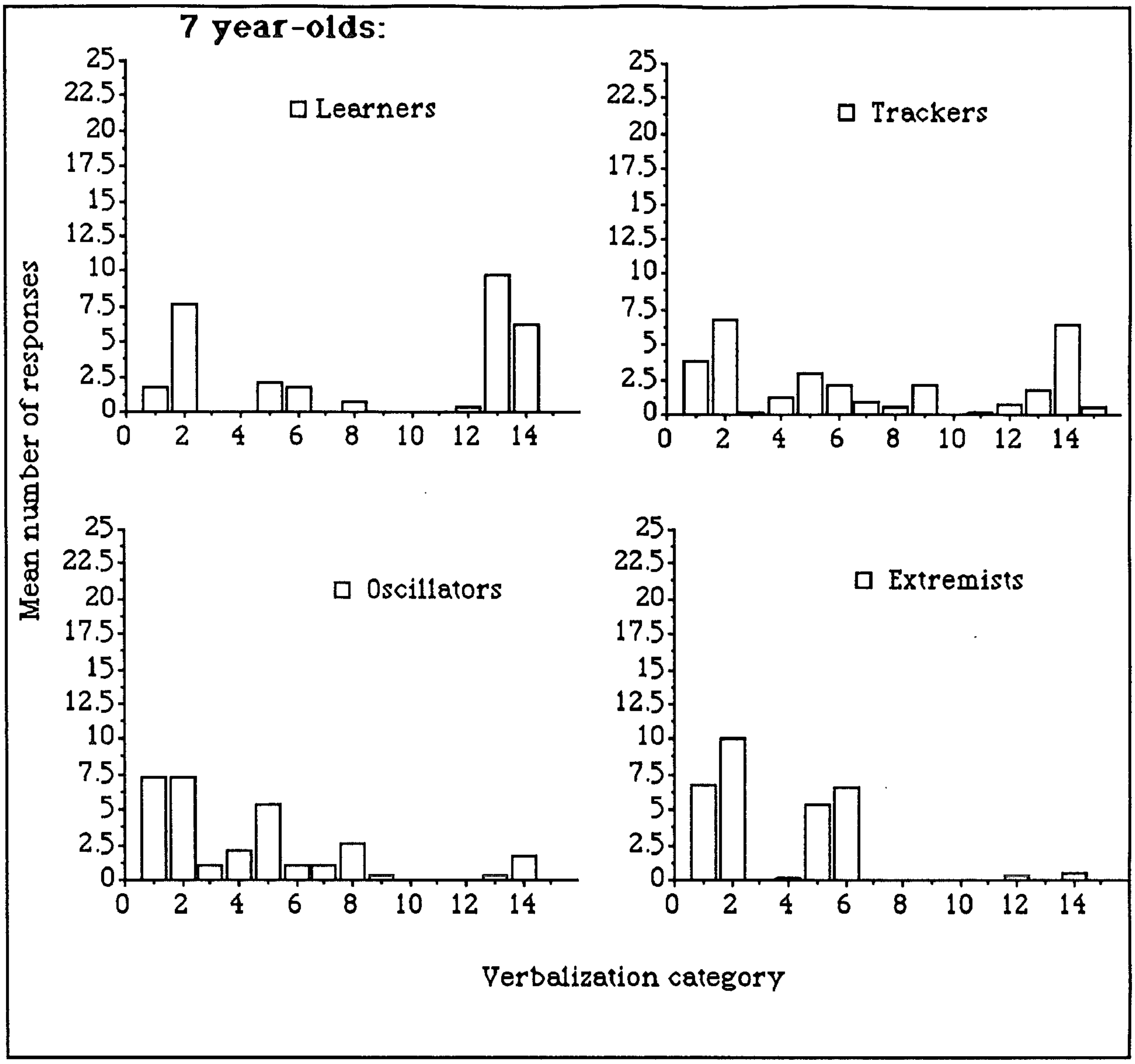


Fig.3.5 cont'd. Mean number of responses in each verbalization category, shown by response typology, for each age group. Figure is continued over page...

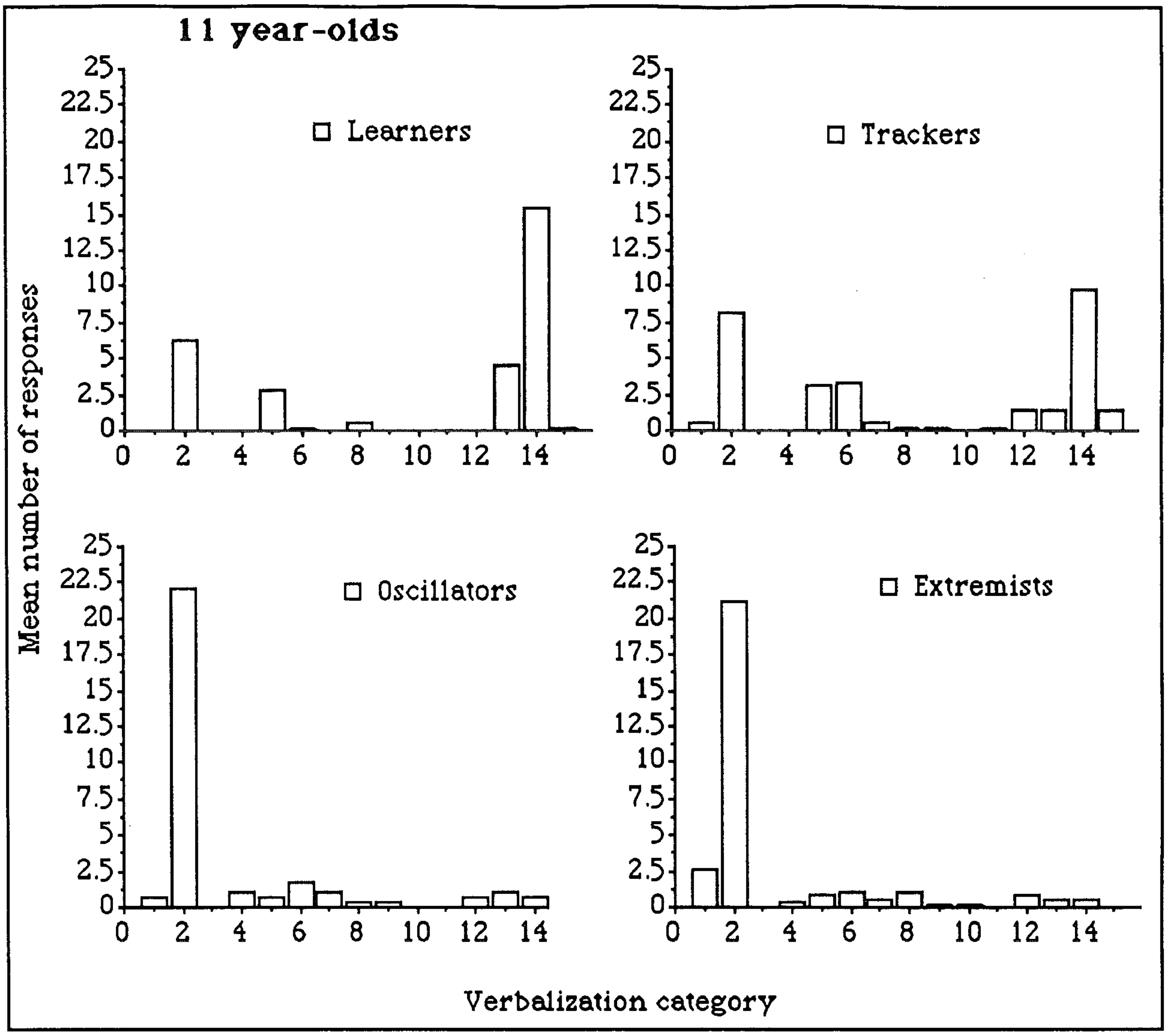


Fig.3.5 cont'd. Mean number of responses in each verbalization category, shown by response typology, for each age group.

The relationship between number of successful button press responses and number of timing verbalizations is also evident when comparing across response typologies and age, as shown in Figure 3.5. Again, there is very little difference in the bar charts for the three 4.5 year-old groups. For both the 7 and 11 year-olds, the charts for the oscillators and extremists are skewed to the left (non-timing categories), while for the trackers and learners there are peaks at both the left and the right (timing categories) of the charts, with learners showing higher peaks to the right.

3.4 Temporal Relationship Between Successful Button Presses and Timing Verbalizations.

There is clearly a relationship in the two older age groups between success on the button press task and number of timing verbalizations. Pouthas et al. (1990) examined the temporal nature of this relationship, which may allow some insight into the issue of verbal control vs epiphenomenal theory, as discussed in the Introduction.

Figure 3.6 shows scattergrams of trial of first successful button press versus trial of first timing verbalization for all three age groups. The solid line represents the matching line such that first successful button press and first timing verbalization occurred on the same trial. As the button press preceded the verbal probe in a trial, points on or below the matching line indicate that the successful button press preceded the insight verbalization. Points lying above the line result from insight verbalizations which preceded first successful button press. Points in line with the infinity symbol on the y-axis, represent subjects who never emitted a successful button press response, while those in line with the infinity symbol on the x-axis represent subjects who never emitted a timing verbalization.

As previously stated, only one 4.5 year-old emitted a timing verbalization, and this occurred after this subject's first successful button press response. All other subjects failed to state any timing strategy, regardless of performance on the button press task.

The data points for the 7 year-old subjects lie both above (n=10), on (n=2), and below (n=8) the matching line[1]. Of those points lying above the line, one subject never emitted a successful button press response, therefore the number of subjects who emitted a timing verbalization prior to their first successful button press response is 9. Ten points lie on or below the matching line. However, of these ten points, 7 subjects never made a timing verbalization, and one other subject made neither a timing verbalization nor a successful button press response.

[1]Where the axis coordinates for two subjects are equivalent, the scattergrams in Figure 3.6 show only one point. The following coordinates represent data points for more than one subject:
4.5 year-olds- (∞, 1), (n=7); (∞, 11), (n=2)
7 year-olds- (∞, 2), (n=2); (∞, 11), (n=2); (1, 3), (n=2)
11 year-olds- (1, 1), (n=3); (1, 3), (n=2)

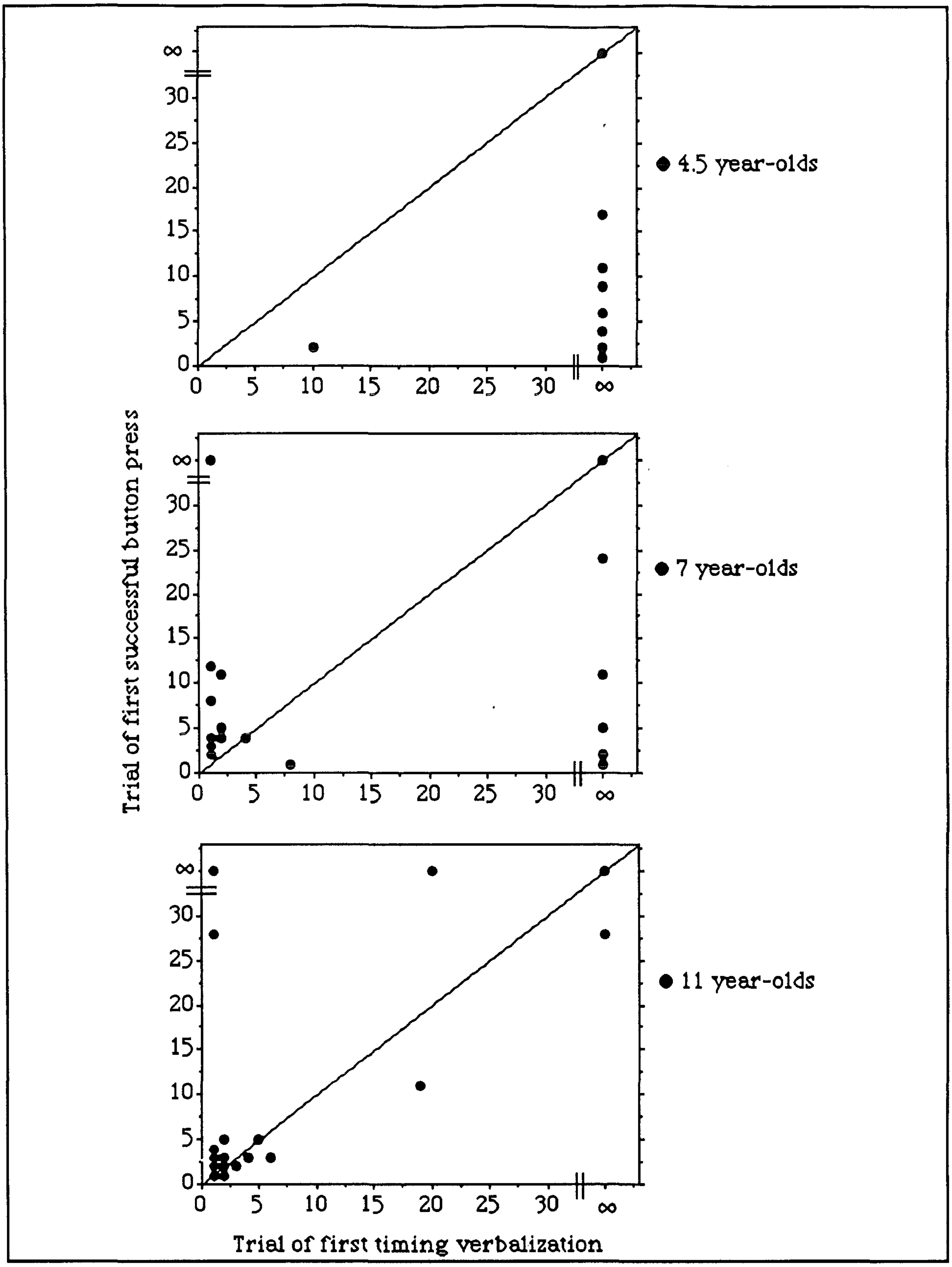


Fig.3.6. Scattergrams showing, by age group, trial of first successful button press versus trial of first timing verbalization. The diagonal line represents perfect matching by trial number, and infinity symbols on x- and y-axes indicate no occurrence of a timing verbalization or successful button press respectively.

Hence, of the eleven 7 year-old subjects who made both a timing verbalization and a successful button press response, for only two subjects did the button press precede the verbalization. Excluding the data of those subjects who failed to emit both a timing verbalization and a successful button press response, the resulting correlation between the two variables is negative but not significantly different from zero ($r = -.37$, $n = 11$, $p > .05$).

Generally, the data from the 11 year-olds cluster more tightly around the matching line than those of the 7 year-olds. The correlation between the two variables, excluding outlying points is positive, but non-significant ($r = .20$, $n=17$, $p > .05$). Excluding two data points for subjects who made no successful button press responses, data points for 7 subjects lie above the matching line. There are 6 points on the line, and 6 points below, including one subject who made no timing verbalization, and one who made neither a timing verbalization nor a successful button press. Thus, a total of 17 subjects made both a timing verbalization and a successful button press response. Six of these 17 made the timing verbalization first, and 11 emitted the button press first. Of these 11, five subjects emitted the first timing verbalization immediately after the first successful button press.

Table 3.3 summarizes these frequencies.

Table 3.3

Frequencies, by age, of the different temporal relationships between first timing verbalization and first successful button press response.

	Successful button press and timing verb'n		**No timing verb'n**	**No succ'ful b' press**	**No verb'n or b' press**
	Verb'n first	B press first			
4.5 years	0	1	14	0	1
7 years	9	2	7	1	1
11 years	7	10	1	2	1

To summarise, of the 4.5 year-olds, no subjects preceded the first successful button press response with a timing verbalization. Eleven 7 year-olds emitted both a timing verbalization and a successful button response and the majority of these subjects (9) made the verbalization first. However, a number of 7 year-olds who made successful button press responses never emitted a timing verbalization. By comparison, most 11 year-olds emitted at least one successful button press and one timing verbalization (n=17), but in only 7 cases did the first timing verbalization precede the first successful button press.

As mentioned earlier, in Figure 3.6 data points for the 11 year-olds appear to cluster more closely around the matching line than those for the 7 year-olds. That is, regardless of whether the successful button press or the timing verbalization came first, the two events seem more closely related in time for the 11 year-olds. This effect was explored more closely by examining the lag between the first timing verbalization and successful button presses. Given the first timing verbalization (on trial n), the frequency of successful button press responses on trial n (preceding the verbalization), trial (n+1), and trial (n+2) was calculated, and the results are expressed graphically in Figure 3.7.

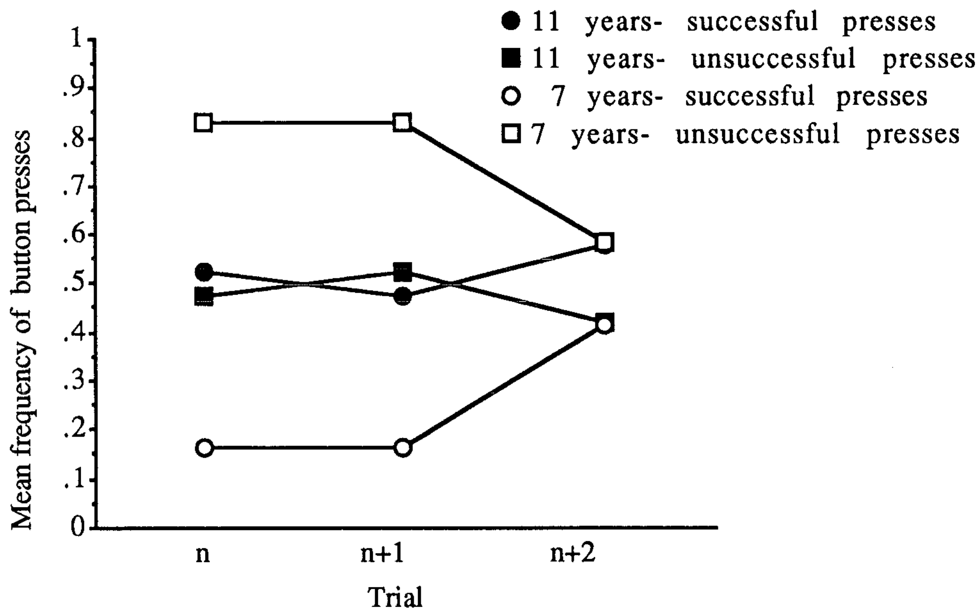


Fig.3.7. Line graph showing, across the 7 and 11 year-old age groups, the mean frequency of successful and unsuccessful button presses on trials n, (n+1), and (n+2), such that trial n is the trial on which the first timing verbalization was emitted.

From Figure 3.7 it is apparent that, for the 11 year-olds, the mean frequencies for successful and unsuccessful button press responses were approximately equal (range= .42-.57) across trials n to (n+2). By comparison, the mean frequencies of successful button press responses on trials n and (n+1) were low (0.17) for the 7 year-olds, but increased at trial (n+2) to 0.42. Thus, for the 11 year-olds the first timing verbalization was generally in closer temporal proximity to a successful button press response than it was for the 7 year-olds.

Pouthas, Droit, Jacquet, and Wearden (1990) arbitrarily restricted their temporal sequence analysis to those subjects for whom at least 50% of button press responses were successful. In the present study, there are ten 11 year-olds and six 7 year-olds who fall into this category. Seven of the 11 year-olds emitted the successful button press first, although for three of these subjects, the first successful button press and the first timing verbalization both occurred on the first trial. Three 11 year-olds verbalized a timing strategy before their first successful button press. Of the 7 year-olds, two emitted a successful button press first, while four verbalized a timing strategy first.

4. DISCUSSION

4.1 Review of Results

The current experiment does not provide clear support for the verbal control theory. Pouthas, Droit, Jacquet and Wearden (1990) claimed that 11 year-old subjects used verbal responses to mediate nonverbal behaviour in the temporal differentiation of button press duration, whereas 4.5 and 7 year-olds did not. On this basis, it was predicted that for 11 year-old subjects in the present study, the concurrent verbal task should interfere with performance more than the nonverbal task, while for younger subjects the two conditions would have a similar effect on differentiation of button press duration. Thus in analysing data for button press duration, an Age X Condition interaction would be expected. Three different dependent variables were tested, namely mean button press duration over trial blocks, duration on last 10 trials, and number of successful responses. All three failed to show an interaction effect.

An alternative prediction was that there may be an effect of condition across all age groups, with subjects in the VI (Verbal Interference) condition performing more poorly on the button press task than subjects in the NI (Nonverbal Interference) condition. Such an effect would indicate that younger children do mediate their timing behaviour verbally, but that the verbal probes and questionnaires fail to elicit their verbal rules. Results did not support this hypothesis either, with no main effect for condition on button press duration. Therefore the failure to find an interaction effect is not secondary to a condition effect across all age groups.

Thus the addition of the interference conditions to the button press task did not result in data which support the verbal control theory.

In addition to the use of direct interference, regular verbal probes were also employed to assess the relations between verbal and nonverbal behaviour on the button press task. This strategy entailed a replication of the procedures used by Pouthas et al. in their verbal probe condition. In the current study only one 4.5 year-old subject emitted a timing verbalization in response to the verbal probes. Moreover, this subject emitted only one such verbalization, a result which is striking given that there were a total of 480 trials for 4.5 year-olds. These results replicate those of Pouthas et al. for 4.5 year-olds in the verbal probe condition.

By comparison to the 4.5 year-olds, the majority of subjects in the older age groups emitted at least one timing verbalization, with only eight 7 year-olds and two 11 year-olds failing to emit any. Analysis confirmed that both the 7 and 11 year-olds emitted significantly more than the 4.5 year-olds. It is conceivable that the difference in emission of timing verbalizations between the youngest and older groups of subjects was secondary to a disparate number of successful button presses. However, data for button press duration failed to reveal a significant effect of age on temporal differentiation, indicating that any differences in verbalizations were not secondary to differences in the number of successful button press responses across age groups. Nor is the difference attributable to fewer verbalizations in the youngest age group, as an analysis of verbal productivity revealed no significant differences in number of verbalizations by age, condition, or age by condition. Thus there was a clear difference in the rate of timing verbalizations for the 4.5 year-olds compared to both older groups, while there was not a corresponding significant difference in the rate of successful button presses.

A comparison of the number of timing verbalizations and number of successful button presses for the 7 and 11 year-olds revealed correlations (.66 and .73 respectively) which were significantly different from zero in both cases. This result, and the finding that most 7 year-olds emitted at least one timing verbalization, are at odds with the study by Pouthas et al. In that experiment, 7 year-olds in the verbal probe condition failed to emit timing verbalizations at all (with the exception of one subject), and hence a relationship between number of timing verbalizations and number of successful button presses was apparent only for the 11 year-old subjects. However, this finding was not supported by the data from the interview condition subjects, which appeared to demonstrate a relationship between number of successful presses and post-session report of a timing strategy for all age groups. The results from the current experiment indicate that the correlation between verbal and nonverbal behaviour is present for 7 and 11 year-olds, but not 4.5 year-olds.

The use of regular verbal probes enabled an analysis of the temporal sequence of changes in verbal and nonverbal behaviour. This analysis showed that for both the 7 and 11 year-olds, of those subjects who emitted both a timing verbalization and a successful button press, some subjects emitted the verbalization first, and some emitted the button press first. For the 7 year-olds, the majority emitted the verbalization first, whereas, the opposite was true for the 11 year-olds. However, a greater number of 7 year-olds than 11 year-olds emitted a successful button press, but never verbalized a timing strategy. These results do not appear to be consistent with those of Pouthas et al. who found that most 11 year-old subjects verbalized a timing strategy before the first successful button press. They arbitrarily restricted the temporal sequence analysis to those subjects for whom at least 50% of responses were successful. As previously mentioned, of the seven 11 year-olds who met this criterion, all but one verbalized a timing strategy prior to the first successful button press. The results from the current study do not replicate this finding. For seven of the ten 11 year-olds who emitted at least 15 successful button presses, the button press preceded the first timing verbalization. However, for three of these subjects, both occurred in the first trial, and the temporal sequence may be an artifact of the way events were programmed in the trial, as the verbal probe followed the button press. Allowing for this, four out of ten 11 year-olds verbalized a timing strategy after the first successful button press, while the same pattern was shown by two of six 7 year-olds. These results do not provide strong support for the verbal control theory.

Figure 3.6 shows an apparent difference between the 7 and 11 year-olds in the temporal proximity of the first successful button press and first verbalization of a timing strategy. A lag analysis demonstrated that for the 11 year-olds, the first timing verbalization was in closer temporal proximity to a successful button press response than it was for the 7 year-olds. Thus, for the 11 year-olds the statement of a timing verbalization was more closely associated in time with the corresponding nonverbal behaviour than it was for the 7 year-olds. It therefore appears that whether the relationship between verbal and nonverbal behaviour is causal or epiphenomenal in nature, it is stronger for 11 year-olds than it is for 7 year-olds.

To summarize, overall the results do not provide much support for the verbal control theory. The verbal and nonverbal interference conditions did not have differential effects on temporal differentiation of the button press response in any of the age groups. While, for the two older age groups there was a positive correlation between number of successful button presses and number of timing verbalizations, the first timing verbalization did not consistently precede the first successful button press.

The data did, however, support the notion that for young children verbal and nonverbal responses are dissociated. However, this effect was only apparent for the youngest age group, and contrary to the results of Pouthas et al., was not characteristic of the responding of 7 year-old subjects.

Of the two main findings which do not support the verbal control theory, the temporal sequence results are least problematic for it. It is conceivable that subjects may experiment with different responses, and upon emitting a successful response, formulate a verbal rule which then mediates ongoing nonverbal responding. To state that the correct verbal rule must be emitted before the first instance of the correct nonverbal response is a very strict interpretation of the verbal control theory. However, the failure of the verbal interference condition to differentially interfere with responding is problematic for the theory. If covert verbal responses are mediating nonverbal responding, then interfering with the ability of the subject to use these verbal responses should have a profound effect on nonverbal responding. The conclusions which can be drawn from this finding are, however, bounded by the limitations of the interference strategy used in this study.

4.2 Limitations of the Present Study

Lack of task acquisition

The biggest limitation of the study is the failure of many subjects to acquire the basic timing task. This reduced the likelihood that any potential differential effect of the two interference conditions on responding would be demonstrated.

In the initial pilot investigation (see Appendix B), where no exposure to the contingency was given prior to the start of the experimental session, none of the 7 year-old subjects (n=6) emitted even one successful button press. All of the subjects pressed the button for a very short period of time. This is contrary to the findings of Pouthas et al. In their study, eight of the eleven 7 year-olds in the verbal probe condition emitted some successful button presses. The most obvious difference between the procedure of Pouthas et al., and the initial pilot investigation reported here, is the addition of the concurrent interference tasks to the present study. The effect of both interference conditions appears to have been to reduce behavioural variability, such that only short button presses were emitted.

In the second pilot investigation, subjects received two practice trials during which they were instructed to press the button and hold it in until the clown told them when it was very, very good. Using this procedure, one of five 7 year-olds, and one of three 11 year-olds achieved more than 10 successful presses, with another 11 year-old emitting 8 successful responses. For the other subjects, isolated successful button presses occurred, but the modal response was to press the button until the green light extinguished and the sad clownface was presented. It was as if these subjects were persisting in following the rule "hold the button in". This may have been attributable to the fact that reinforcement in the practice trials occurred while the subject held the button down, and was not also contingent on the release of the button.

In the final procedure, during the practice trials subjects were prompted to let the button go after holding it down for five seconds, and then received feedback. In this way, the feedback was contingent upon letting go, as well as holding the button down. However, even given this exposure to the contingency, only 34 subjects (7 learners and 27 trackers) showed any sign of task acquisition, while 23 subjects did not succeed in the task at all.

Clearly the contingency-exposure in the practice trials was not sufficient to foster task acquisition in all subjects. A better strategy may have been to shape the 5 second button press response, or to leave the introduction of the interference task until there was some evidence of task acquisition. However, the difficulty with both of these proposals is that they would require considerably more session time. The sessions were reduced to 30 trials in an attempt to minimise the time taken (Pouthas et al. used 40 trials per session). Even with this modification, each session took approximately 40 minutes- a long time for a 4.5 year-old child to remain on task. One disadvantage of reducing the number of trials, however, was that there was less time for subjects to acquire the task. An alternative may have been to use multiple sessions. This would also enable longer exposure to the task, which may increase acquisition. However, using multiple sessions could also increase the chance of subjects discussing the experiment with each other between sessions, and thus may have lead to contamination of the results if subjects adopted other subjects' rules.

Interference task

The interference tasks did not have differential effects on responding. There was not even a trend towards poorer performance by subjects in the VI condition. In fact, the trend went in the other direction with more learners in the VI condition for both the 7 and 11 year-olds, although this did not reach significance. While this may be because the verbal control theory is not correct, there are also some qualifications on the use of the interference strategy in the current experiment.

A difficulty with using the verbal interference strategy in a developmental context is that of achieving equivalent levels of interference across age groups. The stimuli in the two interference conditions were spaced quite widely (3 and 5.5 s intervals) to give children time to respond. It was the experimenter's observation that younger children appeared to often use the full interstimulus interval, sometimes responding to one stimulus when the next stimulus was being presented. For the eldest group of subjects, the intervals may have been too long, resulting in insufficient interference with covert verbal behaviour. An alternative would be to use shadowing of random digit presentation as the verbal interference task. This may be an easier task, enabling shorter interstimulus intervals for younger subjects. The potential limitation with verbal shadowing is that the task may entail simple vocal echoing, rather than fostering interfering covert verbal activity. If this is true, then verbal shadowing would be equivalent to the nonverbal interference task used in the current study.

However, there may be a more fundamental problem with the use of verbal interference strategies. As mentioned in the introduction, previous studies which have used a verbal interference strategy have not controlled for the effect of interference *per se* by using a nonverbal interference control. This study indicates that nonverbal interference tasks may significantly impair performance. For example, in the first pilot investigation the failure of any subject to emit a successful response was in stark contrast to the data presented by Pouthas et al. As previously mentioned, with no interference condition in effect, most 7 year-olds in the verbal probe condition of their study emitted at least one successful button press response. Thus a floor effect may result from the use of interference, such that performance is disrupted even if the interference is not verbal in nature. It may be that the effect of verbal interference strategies is mediated by a general disruption of attention, rather than the actual verbal nature of the concurrent task. This does not necessarily mean that subjects do not use covert verbalizations. The verbal control theory can be salvaged by proposing that general disruption to attention is sufficient to disrupt covert verbalizations. Thus, like the temporal sequence strategy, the verbal interference strategy can potentially result in data which strongly supports the verbal control theory, but cannot disprove it. A fuller investigation of the comparative effects of verbal and nonverbal interference would have required the addition of a no interference control condition to the current study.

4.3. Summary of the Literature, and Implications of the Current Study

<u>Developmental differences in relations between verbal and nonverbal behaviour</u>

There is convergent evidence from a number of sources to suggest that there is a period of development during which children's verbal behaviour is dissociated from their nonverbal behaviour, even though they are able to use language for communication.

Such a theory was originally mooted by Luria, who studied the development of self-regulation through speech. He examined the effect on nonverbal behaviour of instructing young children to self-instruct. His studies showed that it is not until children reach approximately 4 to 4.5 years of age that such self-instructions begin to have a semantically-congruent effect on nonverbal behaviour. While a number of studies failed to support various aspects of Luria's developmental model, they frequently did not examine the specific aspect which related to the dissociation of verbal and nonverbal behaviour. The limitation of the studies cited by Luria is that they did not examine the spontaneous use of self-instructions by children.

Further evidence to support the theory came from studies cited in support of the mediation and production deficiency hypotheses, but these studies examined covert verbal behaviour indirectly, and did not actually assess verbal responses.

The hypothesis that verbal and nonverbal behaviour are dissociated for a period after children become verbal also arose from work within the experimental analysis of behaviour examining developmental differences in FI performance. Bentall, Lowe, and Beasty (1985) found that children aged from 2.5 to 4 years showed FI patterns of responding which did not resemble either adult human or animal patterns, and related verbal rules which were irrelevant to the actual contingency in effect. Pouthas et al (1990) found that both 4.5 and 7 year-old subjects in their verbal probe condition did not produce timing verbalizations, even if they were successful at the nonverbal timing task. The current study failed to replicate this effect with 7 year-olds, but showed a clear effect with 4.5 year-olds, with only one instance of a timing verbalization over a total of 480 trials. This was despite the fact that these children were clearly verbal.

Pouthas et al. (1990) pointed out that younger children may not have verbalized timing strategies simply because the verbal probe used in their study failed to elicit such verbalizations. In the current study, the verbal interference condition provided a potential mechanism to explore this possibility. As mentioned previously, if young children were using covert verbal mediating responses, the VI condition should interfere more with timing behaviour than the NI condition. Results of this study showed approximately equal interference from both conditions, indicating that 4.5 year-olds do not use covert verbal mediating responses. However, this interpretation is restricted by problems, as previously outlined, with the use of interference tasks. Nevertheless, regardless of the limitations of the interference strategy used in the current study, the claim that verbal probes may fail to elicit timing strategies for some subjects is substantially weakened by the general failure of 4.5 year-olds to emit timing verbalizations in both this study and that of Pouthas et al.

Such findings lend considerable support to the theory of dissociation between nonverbal and verbal behaviour at an early age. While this theory, in both the Russian and behavioural traditions, has arisen within a broader context of verbal control theory, it is not dependent on the validity of the verbal control theory. Whether observed correlations between verbal and nonverbal behaviour arise from a causal or epiphenomenal mechanism, the correlations are not apparent for preschool-aged children. Thus whatever the mechanism of association between verbal and nonverbal behaviour, it is not operating for children of this age. The current study indicates that verbal and nonverbal behaviour are associated by the age of 7, but that the association continues to develop and is stronger by the age of 11.

Clearly, elucidating the mechanism by which the association between verbal and nonverbal behaviour operates requires the further exploration of the verbal control vs epiphenomenality debate.

Verbal control vs Epiphenomenal theories

Attempts to determine the validity of the verbal control and epiphenomenal theories of the relations between verbal and nonverbal behaviour have been conspicuous in their failure to rigorously distinguish between the two positions. Several strategies have been employed to explore the issue. These include examining the effect of instructions, post-experimental report, developmental comparisons, analysis of the time-course of changes in verbal and nonverbal behaviour, and methods to interfere with covert verbal behaviour, including both indirect and direct strategies. Most of these experimental strategies have important limitations.

While studies of the effect of instructions on human behaviour show that the statement of verbal rules by others can affect nonverbal responding, they do not cast light on the role of covert self-instruction in the regulation of ongoing behaviour. Thus to demonstrate that nonverbal behaviour can be changed by the presentation of verbal rules does not mean that verbal rules are spontaneously formed and used by the subject to mediate nonverbal responses.

The problem with the use of post-experimental questionnaires and developmental comparisons is that they are both correlational techniques, and hence do not allow a demonstration of causality. That subjects can verbalize a rule following an experimental session, which is consistent with their nonverbal responding during the session, is equally consonant with both the verbal control and epiphenomenal positions. Similarly, the demonstration of changes in schedule performance across ages is at best weak support for the verbal control theory, as a myriad of factors can be postulated to account for developmental differences. Verbal behaviour is only one of them. Developmental studies fail to isolate verbal behaviour as a causal factor in observed differences in schedule performance.

The analysis of the temporal sequence of changes to verbal and nonverbal behaviour is also largely a correlational technique. However, the demonstration that changes in verbal behaviour consistently precede corresponding changes to nonverbal behaviour poses more difficulty for the epiphenomenal position than developmental or post-experimental report strategies. As Wearden (1988) states, to salvage the epiphenomenal position it is necessary to postulate a third common causal variable, such that the threshold for change in verbal behaviour is lower than that for nonverbal behaviour. This argument is not parsimonious, and postulates an unknown, unnamed, and unseen causal variable. However, the difficulty with the temporal sequence strategy is that while it can provide considerable support for the verbal control theory, it is difficult to refute the theory using it. This is because the requirement that verbal changes always precede corresponding nonverbal changes is a strict interpretation of the verbal control theory. Rather, an equally plausible interpretation is that verbal rules may be formed on the basis of experience and practice, and then serve to mediate ongoing responding (Postman & Sassenrath, 1961; Reese, 1989). If this were so, it would be expected that in some cases, at least, the statement of a verbal rule may follow the initial demonstration of the corresponding nonverbal behaviour. This situation arose in the current experiment. The finding that for some subjects the statement of the timing rule preceded the first successful button press response, while for other subjects the reverse temporal sequence was true, is still consistent with the verbal control theory. However, it is also less difficult for the epiphenomenal position than a finding that the verbal rule consistently preceded the corresponding nonverbal response. Therefore, the finding has little power in differentiating between the two positions.

More promising strategies are those which attempt to alter covert verbalizations, and observe the effect on nonverbal responding. The indirect and direct interference strategies fall into this category. Results from the three studies using direct interference have not been consistent, and have for the most part been complicated by the use of instructions regarding the reinforcement contingency, and the failure to control for the effect of interference *per se.* The current experiment indicates that a major problem with direct verbal interference strategies may be that of isolating the role of the verbal aspect of the interference. Nonverbal interference in the present study appeared to disrupt performance at least as much as verbal interference, indicating a potential floor effect. If this is so, the verbal interference strategy may be in the same position as the temporal sequence strategy, i.e., it is unable to refute the verbal control theory.

The nature of disruption resulting from concurrent verbal activity could be further explored in an experiment comparing the performance of uninstructed adult human subjects on FI schedules of reinforcement with verbal, nonverbal, or no interference condition in effect. The patterning of FI schedule performance may be sensitive to any qualitative differences resulting from verbal and nonverbal interference.

Studies using indirect interference have consistently supported the verbal control theory. This is perhaps the most promising technique for continuing to explore the verbal control vs epiphenomenality debate. It is also a promising technique for exploring the action of verbal interference strategies. Lowe and Hughes (in Lowe, 1979), found that concurrent verbalization affected performance in a standard FI condition, but not in a digital clock condition. This is perhaps one of the strongest findings in support of the verbal control theory, as it demonstrates a convergence of effects. Both strategies are hypothesized to interfere with covert verbalization, thus adding one to the other should have no greater effect than one alone. Even stronger support would be lent to the theory if the effect held in the reverse order, i.e., if adding a digital clock procedure after the introduction of concurrent verbalization failed to change responding. It also allows another way to compare the effect of concurrent verbal and nonverbal tasks. If both are operating by the same mechanism, then a nonverbal shadowing task should not affect performance when combined with a digital clock condition.

4.4. Conclusion.

The difficulty facing researchers in the debate over the verbal control and epiphenomenal theories is to use experimental strategies which will enable conclusive support of one of the theories. The strategies used in the current experiment, namely verbal interference and temporal sequence analysis, can potentially result in data which strongly supports the verbal control theory, but have limited power to disprove this theory. The latter situation arose in the present study. While the results did not demonstrate the validity of the verbal control theory, the theory can none-the-less be salvaged by the addition of further assumptions.

The current study did, however, add to the growing weight of evidence that for preschool children verbal and nonverbal behaviour is dissociated. While previously this hypothesis has been examined within the context of verbal control theory, it is also interpretable within the context of epiphenomenal theory.

REFERENCES

Azrin, N.H. (1958). Some effects of noise on human behavior. *Journal of the Experimental Analysis of Behavior, 1,* 183-200.

Baron, A., & Galizio, M. (1983). Instructional control of human operant behavior. *The Psychological Record, 33,* 495-520.

Baron, A., & Perone, M. (1982).The place of the human subject in the operant laboratory. *The Behavior Analyst, 5,* 143-158.

Baron, A., Kaufman, A., & Stauber, K.A. (1969). Effects of instructions and reinforcement-feedback on human operant behavior maintained by fixed-interval reinforcement. *Journal of the Experimental Analysis of Behavior, 12,* 701-712.

Beiswenger, H. (1968). Luria's model of the verbal control of behavior. *Merrill-Palmer Quarterly, 19,* 117-135.

Bentall, R.P., Lowe, C.F., & Beasty, A. (1985). The role of verbal behavior in human learning: II. Developmental differences. *Journal of the Experimental Analysis of Behavior, 43,* 165-181.

Bloor, D. (1977). The regulatory function of language: An analysis and contribution to the current controversy over the Soviet theory. In P.J. Morton & J.C. Marshall (Eds.), *Psycholinguistics, Developmental and Pathological* (pp. 73-97). Ithaca, N.Y.: Cornell University Press.

Brownstein, A.J., & Shull, R.L. (1985). A rule for the use of the term, "Rule-governed behavior". *The Behavior Analyst, 8,* 265-267.

Buskist, W.F., Bennett, R.H., & Miller, H.L. (1981). Effects of instructional constraints on human fixed-interval performance. *Journal of the Experimental Analysis of Behavior, 35,* 217-225.

Buskist, W.F., & Miller, H.L. (1981). The analysis of human operant behavior: A brief census of the literature, 1958-1981. *The Behavior Analyst, 4,* 137-141.

DeCasper, A.J., & Zeiler, M.D. (1972). Steady-state behavior in children: A method and some data. *Journal of Experimental Child Psychology, 13,* 231-239.

Dulany (Jr.), D.E. & O'Connell, D.C. (1963). Does partial reinforcement dissociate verbal rules and the behavior they might be presumed to control? *Journal of Verbal Learning and Verbal Behavior, 2,* 361-372.

Felton, M., & Lyon, D.O. (1966). The post-reinforcement pause. *Journal of the Experimental Analysis of Behavior, 9 (2),* 131- 134.

Ferster, C.B., & Skinner, B.F. (1957). *Schedules of Reinforcement.* New York: Appleton-Century-Crofts.

Flavell, J.H., Beach, D.R., & Chinsky, J.M. (1966). Spontaneous verbal rehearsal in a memory task as a function of age. *Child Development, 37,* 283-299.

Galizio, M. (1979). Contingency-shaped and rule-governed behavior: Instructional control of human loss avoidance. *Journal of the Experimental Analysis of Behavior, 31,* 53-70.

Greenspoon, J. (1963). Reply to Spielberger and DeNike: "Operant conditioning of plural nouns: A failure to replicate the Greenspoon effect". *Psychological Reports, 12,* 29-30.

Hake, D. (1982). The basic-applied continuum and the possible evolution of human operant social and verbal research. *The Behavior Analyst, 5,* 21-28.

Hanson, H.M., Campbell, E.H., & Witoslawski, J.J. (1962). FI length and performance on an FIFR chain schedule of reinforcement. *Journal of the Experimental Analysis of Behavior, 5,* 331-333.

Harzem, P., Lowe, C.F., & Bagshaw, M. (1978). Verbal control in human operant behavior. *The Psychological Record, 28,* 405-423.

Hayes, S.C., Brownstein, A.J., Haas, J.R., & Greenway, D.E. (1986). Instructions, multiple schedules, and extinction: Distinguishing rule-governed from schedule-controlled behavior. *Journal of the Experimental Analysis of Behavior, 46,* 137-147.

Hayes, S.C., Brownstein, A.J., Zettle, R.D., Rosenfarb, I., & Korn, Z. (1986). Rule-governed behavior and sensitivity to changing consequences of responding. *Journal of the Experimental Analysis of Behavior, 45,* 237-256.

Hayes, S.C., Zettle, R.D., & Rosenfarb, I. (1989). Rule-following. In S.C. Hayes (Ed.), *Rule-Governed Behavior: Cognition, Contingencies, and Instructional Control* (pp. 191-220). New York: Plenum Press.

Holland ,J.G. (1957). Technique for behavioral analysis of human observing. *Science, 125,* 348-350.

Jarvis, P.E. (1968). Verbal control of sensory-motor performance: A test of Luria's hypothesis. *Human Development, 11,* 172-183.

Joynt, D., & Cambourne, B. (1968). Psycholinguistic development and the control of behaviour. *British Journal of Educational Psychology, 38,* 249-260.

Kaufman, A., Baron, A., & Kopp, R.E. (1966). Some effects of instructions on human operant behavior. *Psychonomic Monograph Supplements, 1,* 243-250.

Kendler, H.H., & Kendler, T.S. (1962). Vertical and horizontal processes in problem solving. *Psychological Review, 69,* 1-16.

Kendler, T.S., & Kendler, H.H. (1959). Reversal and nonreversal shifts in kindergarten children. *Journal of Experimental Psychology, 58,* 56-60.

Kendler, T.S., Kendler, H.H., & Wells, D. (1960). Reversal and nonreversal shifts in nursery school children. *Journal of Comparative and Physiological Psychology, 53,* 83-88.

Laties, V.G. & Weiss, B. (1962). Effects of alcohol on timing behavior. *Journal of Comparative and Physiological Psychology, 55,* 85-91.

Laties, V.G., & Weiss, B. (1963). Effects of a concurrent task on fixed-interval responding in humans. *Journal of the Experimental Analysis of Behavior, 6,* 431-436.

Leander, J.D., Lippman, L.G., & Meyer, M.E. (1968). Fixed interval performance as related to subjects' verbalizations of the reinforcement contingency. *The Psychological Record, 18,* 469- 474.

Lippman, L.G., & Meyer, M.E. (1967). Fixed interval performance as related to instructions and to subjects' verbalizations of the contingency. *Psychonomic Science, 8, (4),* 135-136.

Long, E.R., Hammack, J.R., May, F., & Campbell, B.J. (1958). Intermittent reinforcement of operant behavior in children. *Journal of the Experimental Analysis of Behavior, 1,* 315-339.

Lowe, C.F. (1979). Determinants of human operant behaviour. In M.D. Zeiler & P. Harzem (Eds.), *Advances in analysis of behaviour: Vol. 1. Reinforcement and the organization of behaviour* (pp. 159-192). Chichester, England: Wiley.

Lowe, C.F. (1983). Radical behaviorism and human psychology. In G.C.L. Davey (Ed.), *Animal models of human behavior: Conceptual, evolutionary and neurobiological perspectives* (pp. 71-93). Chichester, England: Wiley.

Lowe, C.F., Beasty, A., & Bentall, R.P. (1983). The role of verbal behavior in human learning: Infant performance on fixed-interval schedules. *Journal of the Experimental Analysis of Behavior, 39,* 157-164.

Lowe, C.F., & Harzem, P. (1977). Species differences in temporal control of behavior. *Journal of the Experimental Analysis of Behavior, 28,* 189-201.

Lowe, C.F., Harzem, P., & Bagshaw, M. (1978). Species differences in temporal control of behavior II: Human performance. *Journal of the Experimental Analysis of Behavior, 29,* 351-361.

Lowe, C.F., Harzem, P., & Hughes, S. (1978). Determinants of operant behaviour in humans: some differences from animals. *Quarterly Journal of Experimental Psychology, 30,* 373-386.

Lowe, C.F., & Higson, P.J. (1981). Self-instructional training and cognitive behaviour modification: A behavioural analysis. In G.C.L. Davey (Ed.), *Applications of Conditioning Theory* (pp. 162-188). London: Methuen.

Luria, A.R. (1932). *The Nature of Human Conflicts.* New York: Liveright.

Luria, A.R. (1957). The role of language in the formation of temporary connections. In B. Simon (Ed.), *Psychology in the Soviet Union* (pp. 115-129). Stanford: Stanford University Press.

Luria, A.R. (1959). The directive function of speech in development and dissolution. *Word, 15,* 341-352.

Luria, A.R. (1960). Verbal regulation of behavior. In M.A.Brazier (Ed.), *The Central Nervous System and Behavior* (pp. 359-423). Madison, N.J.: Madison Printing Company.

Luria, A.R. (1961)a. The genesis of voluntary movements. In N. O'Connor (Ed.), *Recent Soviet Psychology* (pp. 165-185). New York; Liveright.

Luria, A.R. (1961)b. *The Role of Speech in the Regulation of Normal and Abnormal Behaviour.* London: Pergammon Press.

Luria, A.R. (1981). *Language and Cognition.* New York: Wiley.

Mackintosh, N.J. (1983). *Conditioning and Associative Learning.* Oxford: Oxford University Press.

Matthews, B.A., Shimoff, E., Catania, A.C., & Sagvolden, T. (1977). Uninstructed human responding: Sensitivity to ratio and interval contingencies. *Journal of the Experimental Analysis of Behavior, 27,* 453-467.

Moely, B.E., Olson, F.A., Halwes, T.G., & Flavell, J.H. (1969). Production deficiency in young children's clustered recall. *Developmental Psychology, 1,* 26-34.

Miller, S.A., Shelton, J., & Flavell, J.H. (1970). A test of Luria's hypotheses concerning the development of verbal self-regulation. *Child Development, 41,* 651-665.

Morse, W.H. (1966). Intermittent reinforcement. In W.K. Honig (Ed.), *Operant Behavior: Areas of Research and Application* (pp. 52-108). New York: Appleton-Century-Crofts.

Parrot, L.J. (1987). Rule-governed behavior: An implicit analysis of reference. In S. Modgil & C. Modgil (Eds.), *B.F. Skinner: Consensus and Controversy* (pp. 265-276). NY: Falmer Press.

Perone, M. Galizio, M., & Baron, A. (1988). The relevance of animal-based principles in the laboratory study of human operant conditioning. In G. Davey & C. Cullen (Eds.), *Human Operant Conditioning and Behavior Modification* (pp. 59-85). Chichester, England: Wiley.

Peterson, L.R. (1969). Concurrent verbal activity. *Psychological Review, 76 (4),* 376-386.

Postman, L., & Sassenrath, J. (1961). The automatic action of verbal rewards and punishments. *The Journal of General Psychology, 65,* 109-136.

Pouthas, V., Droit, S., Jacquet, A-Y., & Wearden,J.H. (1990). Temporal differentiation of response duration in children of different ages: Developmental changes in relations between verbal and nonverbal behavior. *Journal of the Experimental Analysis of Behavior, 53,* 21-31.

Pouthas, V., & Jacquet, A-Y. (1987). A developmental study of timing behavior in 4 1/2- and 7-year-old children. *Journal of Experimental Child Psychology, 43,* 282-299.

Reese, H.W. (1962). Verbal mediation as a function of age level. *Psychological Bulletin, 59,* 502-509.

Reese, H.W. (1989). Rules and rule-governance: Cognitive and behavioristic views. In S.C. Hayes (Ed.), *Rule-Governed Behavior: Cognition, Contingencies, and Instructional Control* (pp. 3-84). New York: Plenum Press.

Rondal, J.A. (1976). Investigation of the regulatory power of the impulsive and meaningful aspects of speech. *Genetic Psychology Monographs, 94,* 3-33.

Schlinger, H., & Blakely, E. (1987). Function-altering effects of contingency-specifying stimuli. *The Behavior Analyst, 10,* 41-45.

Shimoff, E., Catania, A.C., & Matthews, B.A. (1981). Uninstructed human responding: Sensitivity of low-rate performance to schedule contingencies. *Journal of the Experimental Analysis of Behavior, 36,* 207-220.

Skinner, B.F. (1938). *The Behavior of Organisms.* New York: Appleton-Century-Crofts.

Skinner, B.F. (1957). *Verbal Behavior.* New York: Appleton-Century-Crofts.

Skinner, B.F. (1969). *Contingencies of Reinforcement: A Theoretical Analysis.* New York: Appleton-Century-Crofts.

Skinner, B.F. (1974). *About Behaviorism.* New York: Alfred A. Knopf.

Skinner, B.F. (1984). The operational analysis of psychological terms. *The Behavioral and Brain Sciences, 7,* 547-553.

Sokolov, A.N. (1972). *Inner Speech and Thought.* New York: Plenum Press.

Tolman, E.C. (1938). The determiners of behavior at a choice point. *Psychological Review, 45,* 1-41.

Vaughan, M. (1987). Rule-governed behavior and higher mental processes. In S. Modgil & C. Modgil (Eds.), *B.F. Skinner: Consensus and Controversy* (pp. 257-264). London: Falmer.

Vaughan, M. (1989). Rule-governed behavior in behavior analysis: A theoretical and experimental history. In S.C. Hayes (Ed.), *Rule-Governed Behavior: Cognition, Contingencies, and Instructional Control* (pp. 97-118). New York: Plenum.

Verplanck, W.S. (1962). Unaware of where's awareness: Some verbal operants-notates, monents, and notants. In C.W. Eriksen (Ed.), *Behavior and Awareness: A Symposium of Research and Interpretation* (pp. 130-158). Durham, N.C.: Duke University Press.

Wearden, J.H. (1988). Some neglected problems in the analysis of human operant behavior. In G. Davey & C. Cullen (Eds.), *Human Operant Conditioning and Behavior Modification* (pp. 197-224). Chichester, England: Wiley.

Wearden, J.H., & Shimp, C.P. (1985). Local temporal patterning of operant behavior in humans. *Journal of the Experimental Analysis of Behavior, 44,* 315-324.

Weiner, H. (1964)a. Conditioning history and human fixed-interval performance. *Journal of the Experimental Analysis of Behavior, 7,* 383-385.

Weiner, H. (1964)b. Response cost and fixed-ratio performance. *Journal of the Experimental Analysis of Behavior, 7,* 79-81.

Weiner, H. (1969). Controlling human fixed-interval performance. *Journal of the Experimental Analysis of Behavior, 12,* 349- 373.

Weiner, H. (1970). Human behavioral persistence. *The Psychological Record, 20,* 445-456.

Weiner, H. (1982). Histories of response omission and human operant behavior under a fixed-ratio schedule of reinforcement. *The Psychological Record, 32,* 409-434.

Weiner, H. (1983). Some thoughts on discrepant human-animal performances under schedules of reinforcement. *The Psychological Record, 33,* 521-532.

Whaley, D.L., & Malott, R.W. (1971). *Elementary Principles of Behavior.* New York: Appleton-Century-Crofts.

Wilson, M.P. (1954). Periodic reinforcement interval and number of periodic reinforcements as parameters of response strength. *Journal of Comparative and Physiological Psychology, 47,* 51- 56.

Wozniak, R.H. (1972). Verbal regulation of motor behavior- Soviet research and non-Soviet replications. *Human Development, 15,* 13-57.

Zeiler, M.D., & Kelley, C.A. (1969). Fixed-ratio and fixed-interval schedules of cartoon presentation. *Journal of Experimental Child Psychology, 8,* 306-313.

Zettle, R.D., & Hayes, S.C. (1982). Rule-governed behavior: A potential theoretical framework for cognitive-behavioral therapy. In P.C. Kendall (Ed.), *Advances in Cognitive-Behavioral Research and Therapy. Vol. 1* (pp. 73-118). New York: Academic Press.

APPENDICES

APPENDIX A

Computer programme for running the experiment.

```
1 REM THIS PROGRAM CALLED PCT-TEST WAS WRITTEN BY NEVILLE BLAMPIED
2 REM FOR PHILLIPA CAMPBELL-TIE'S MASTERS THESIS RESEARCH, 1991.
3 REM IT REQUIRES A NO-SLOT CLOCK TO BE FITTED IN HARDWARE AND
  THE MACHINE-LANGUAGE PROGRAM "CLOCKREAD" TO BE AVAILABLE ON THE SAME
  DISC
10  REM  THIS VERSION OF PCT-TEST IS SAME AS OTHER EXCEPT
     THAT LINE 1588 HAS (PT) NOT PT
100  HOME : CLEAR
102 D$ =  CHR$ (4)
103  PRINT D$;"BLOAD CLOCKREAD,A8192"
300  GOSUB 4000
400  GOSUB 8000
500  GOSUB 3200
600  GOSUB 5000
900  HOME : DIM SC(50): DIM R(50):T = 0
905  HOME : PRINT "READY FOR SET OF ACTUAL TRIALS ?"
910  PRINT "HIT [RETURN] TO PROCEED    ";R$
920  GET R$
1000  REM   TRIAL EXECUTE
1005  PRINT : PRINT "START TAPE PLAY": PRINT
1020 T = T + 1: REM   INCREMENT TRIAL COUNTER
1025  CALL 8192
1027 TA = ( PEEK (8200) * 60) + ( PEEK (8201)) + ( PEEK (8202) / 100)
1029  FOR I = 1 TO 500: NEXT
1030  CALL 8192:PT = ( PEEK (8200) * 60) + ( PEEK (8201)) + ( PEEK (8202) / 100)
1031  IF (PT) < (TA + 15) THEN  GOTO 1029
1040  POKE RO(1),0
1042  PRINT "                                                GREEN ON"
1050 V =  PEEK (49249)
1055  CALL 8192:PT = ( PEEK (8200) * 60) + ( PEEK (8201)) + ( PEEK (8202) / 100)
1057  IF PT > (TA + 25) GOTO 9000: REM   ABORT IF NO KEY PRESS
1060  IF V < 127.5 GOTO 1050: REM   LOOP UNTIL KEY PRESSED
1070  CALL 8192
1080 ST = ( PEEK (8200) * 60) + ( PEEK (8201)) + ( PEEK (8202) / 100)
1090  POKE RO(2),0
1092  PRINT "                                                RED ON"
1100 V =  PEEK (49249)
1110  IF V < 128 GOTO 1500
1120  CALL 8192
1130 PT = ( PEEK (8200) * 60) + ( PEEK (8201)) + ( PEEK (8202) / 100)
1140 ET = PT - ST: REM   PRESENT - START TIME
1145  PRINT "PRESSING KEY"
1150  IF ET > 9.999 GOTO 1500
1160  GOTO 1100
1500  CALL 8192
1510 FT = ( PEEK (8200) * 60) + ( PEEK (8201)) + ( PEEK (8202) / 100)
1520  POKE RF(1),0: POKE RF(2),0
1522  PRINT "                                             GREEN & RED OFF"
1530 SC(T) = FT - ST:
1532  REM
1535  PRINT "SCORE THIS TRIAL WAS  ";SC(T)
1540  GOSUB 7000
1550  PRINT : PRINT : PRINT "PLEASE WAIT - SAVING DATA IN ITI"
```

```
1575  PRINT D$"OPEN"ID$: PRINT D$"WRITE"ID$
1576  FOR I = 1 TO T: PRINT SC(I): NEXT
1577  PRINT D$"CLOSE"ID$
1581  IF T = 30 THEN  INPUT "HOW MANY EXTRA TRIALS ?";X
1582  IF T > 29 + X GOTO 2000
1584 TA = ( PEEK (8200) * 60) + ( PEEK (8201)) + ( PEEK (8202) / 100)
1586  FOR I = 1 TO 5000: NEXT
1587  CALL 8192:PT = ( PEEK (8200) * 60) + ( PEEK (8201)) + ( PEEK (8202) / 100)
1588  IF (PT) < (TA + 30) GOTO 1586
1589  CALL  - 198
1590  PRINT : PRINT : PRINT : INVERSE : PRINT "READY FOR TRIAL";T + 1
1600  NORMAL
1605  PRINT "HIT 'Y' TO CONTINUE"
1610  GET R$: IF R$ = "Y" THEN  GOTO 1000
1620  GOTO 1590
2000  PRINT "DO YOU WANT A LIST OF DATA ?
2005  PRINT "FOR SUBJECT   ";ID$: PRINT
2010  INPUT "'Y'= YES 'N' = NO  ";R$
2012  IF R$ = "N" GOTO 2500
2015  SPEED= 30
2020  FOR I = 1 TO T
2030  PRINT "SCORE ON TRIAL ";I;" = ";SC(I)
2035  NEXT
2040  SPEED= 255
2500  PRINT "DO YOU WANT TO RUN ANOTHER SUBJECT ? "
2510  PRINT " 'Y' = YES: 'N' = NO": GET R$
2520  IF R$ = "Y" GOTO 100
2999  END
3200  REM   INITIALIZE OUTPUT CARD
3210 OA =  - 16256 + (16 * 7)
3220 RO(1) = OA + 1:RO(2) = OA + 3:RO(3) = OA + 5:R0(4) = OA + 7
3230 RF(1) = OA:RF(2) = OA + 2:RF(3) = OA + 4:RF(4) = OA + 6
3240  FOR I = 1 TO 4
3250  POKE RF(I),0
3260  RETURN
4000  REM   DATE PRINT SUBROUTING
4010  CALL 8192
4015  HOME
4020  PRINT "TODAY IS "; PEEK (8197);"/"; PEEK (8196);"/ 19"; PEEK (8195)
4030 DY$ =  STR$ ( PEEK (8197))
4040 MN$ =  STR$ ( PEEK (8196))
4050 DTE$ = DY$ + "/" + MN$
4055  FOR I = 1 TO 3000: NEXT
4060  RETURN
5000  REM    PRACTICE TRIALS
5005  HOME : PRINT "START TAPE PLAY": PRINT
5025  CALL 8192
5027 TA = ( PEEK (8200) * 60) + ( PEEK (8201)) + ( PEEK (8202) / 100)
5029  FOR Z = 1 TO 500: NEXT
5030  CALL 8192:PT = ( PEEK (8200) * 60) + ( PEEK (8201)) + ( PEEK (8202) / 100)
5031  IF (PT) < (TA + 15) GOTO 5029
5040  POKE RO(1),0
5042  PRINT "                                                  GREEN ON"
5050 V =  PEEK (49249)
5060  IF V < 127.5 GOTO 5050: REM   LOOP UNTIL KEY PRESSED
```

```
5070  CALL 8192
5080 ST = ( PEEK (8200) * 60) + ( PEEK (8201)) + ( PEEK (8202) / 100)
5090  POKE RO(2),0
5092  PRINT "                                               RED ON"
5100 V =  PEEK (49249)
5110  IF V < 128 GOTO 5500
5120  CALL 8192
5130 PT = ( PEEK (8200) * 60) + ( PEEK (8201)) + ( PEEK (8202) / 100)
5140 ET = PT - ST: REM   PRESENT - START TIME
5145  PRINT "PRESSING KEY"
5150  IF ET > 9.999 GOTO 5500
5160  GOTO 5100
5500  CALL 8192
5510 FT = ( PEEK (8200) * 60) + ( PEEK (8201)) + ( PEEK (8202) / 100)
5520  POKE RF(1),0: POKE RF(2),0
5522  PRINT "                                            GREEN & RED OFF"
5530 TT(T) = FT - ST
5535  PRINT "SCORE THIS TRIAL WAS  ";TT(T)
5540  PRINT "ANOTHER PRACTICE ? 'Y' = YES"
5550  GET R$
5560  IF R$ = "Y" THEN  GOTO 5005
5570  RETURN
7000  REM   GIVE FEEDBACK MESSAGE
7010  IF SC(T) < 2.5 GOTO 7100
7015  IF SC(T) > 7.5 GOTO 7100
7020  IF SC(T) > 4.0 THEN  GOTO 7200
7070  PRINT "OK": GOTO 7210
7100  PRINT : PRINT "NOT GOOD ": GOTO 7210
7200  IF SC(T) < 6.0 THEN  PRINT "VERY  ! VERY ! GOOD !!": GOTO 7210
7205  PRINT : PRINT "OK"
7210  RETURN
8000  REM   PROGRAM GREET AND ID
8005  HOME : VTAB 10: HTAB 6
8010  PRINT "WELCOME TO PHILIPA'S EXPERIMENT"
8020  PRINT : PRINT : PRINT "WHICH SCHOOL ARE YOU AT ?"
8030  INPUT SCH$
8040  PRINT : PRINT : PRINT "WHAT ARE THE INITIALS OF THE CHILD ?": PRINT
8050  INPUT KID$
8060  HOME : VTAB 10: HTAB 6
8070  PRINT "CONFIRMING: SCHOOL IS ";SCH$: PRINT
8075  PRINT "                 & CHILD IS ";KID$: PRINT
8080  PRINT "IS THIS OK ? HIT 'N' TO CHANGE,": PRINT
8085  PRINT " 'RETURN' IF OK"
8090  INPUT R$
8100  IF R$ = "N" GOTO 8020
8105 ID$ = SCH$ + "/" + KID$ + "/" + DTE$
8110  RETURN
9000  REM   TRIAL ABORT ROUTINE
9010  PRINT "TRIAL ABORTED WITH NO KEYPRES WITHIN 25 SEC"
9020  POKE RF(1),0: POKE RF(2),0
9030 SC(T) =  - 999
9040  PRINT "PRESS 'RETURN' WHEN YOU ARE READY TO PROCEED"
9050  GET R$
9060  GOTO 1550
```

APPENDIX B

The procedure for the current study was refined following two pilot investigations which are reported here.

The apparatus and materials for the pilot studies were the same as those for the current study.

Pilot Investigation 1

a. Subjects

Six 7 year-old girls took part in the first pilot investigation. The age range of the subjects was 91 to 94 months, with a mean age of 93.3 months (7years 9.3 months). All six were pupils of Mairehau primary school.

b. Procedure

The procedure of the first pilot investigation was the same as that of the main study, except that the two practice trials during which subjects were exposed to the reinforcement contingency were not included.

c. Results

None of the six subjects emitted a successful button press response (where "successful" button presses are those lying within the range of 2.5-7.5s). All subjects pressed the button for short durations, with five of the subjects consistently pressing for less than 1.0s. The sixth subject pressed the button for longer than 1.0s on a number of trials, but the longest press was only 1.33s long.

Given the failure of all six subjects to contact the reinforcement contingency, it was decided to add some more practice trials during which there was forced exposure to the contingency.

Pilot Investigation 2

a. Subjects

Five 7 year-olds (3 girls, 2 boys) and three 11 year-olds (2 girls, 1 boy) took part in the second pilot investigation. The 7 year-olds ranged in age from 91 to 95 months, with a mean age of 92.8 months (7years 8.8months). The 11 year-olds ranged in age from 132 to 135 months, with a mean age of 133.3 months (11years 1.3months). All subjects were pupils of Mairehau primary school.

b. Procedure

The procedure was the same as that for the main study, and included the two practice trials during which subjects were exposed to the reinforcement contingency. However, the procedure on these practice trials was slightly different to that of the main study. The instructions for these practice trials were as follows:

Now let's have another practice turn. This time, keep playing the (word/singing) game, but when the button lights up you hold the button down until the clown tells you when it is very, very good.

The smiling clown, and accompanying verbal feedback, were presented when button press duration reached 5 seconds.

c. Results

Four of the 7 year-olds emitted only one successful button press, while the other emitted 22. For the three 11 year-olds the number of successful button presses were 3, 8, and 13.

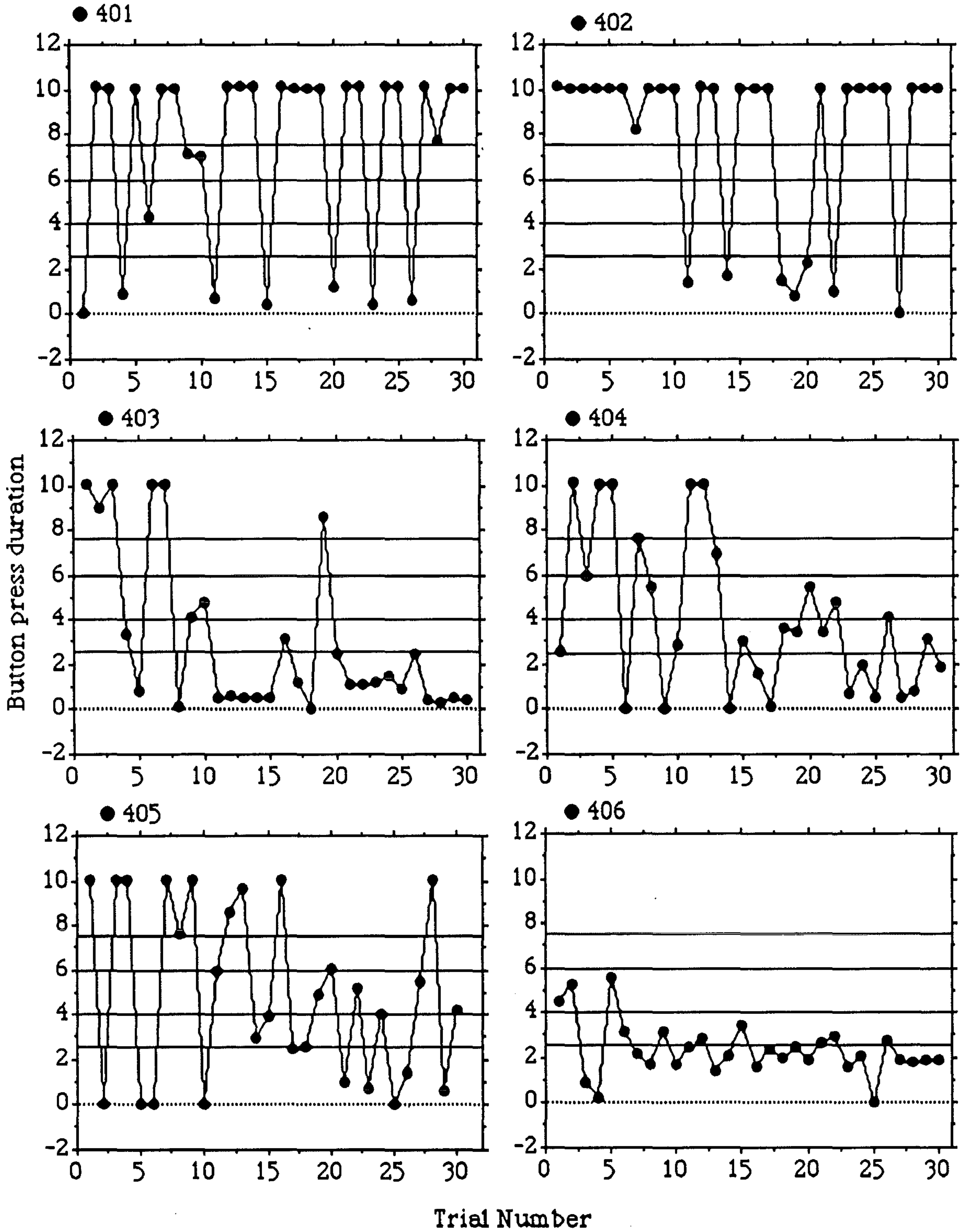
For the unsuccessful 7 year-olds, the modal response (mean number of trials= 25.7) was to press the button until the green light extinguished and the sad clown-face was presented. This was also the modal response (number of trials=26) for the 11 year-old subject who emitted only 3 successful presses.

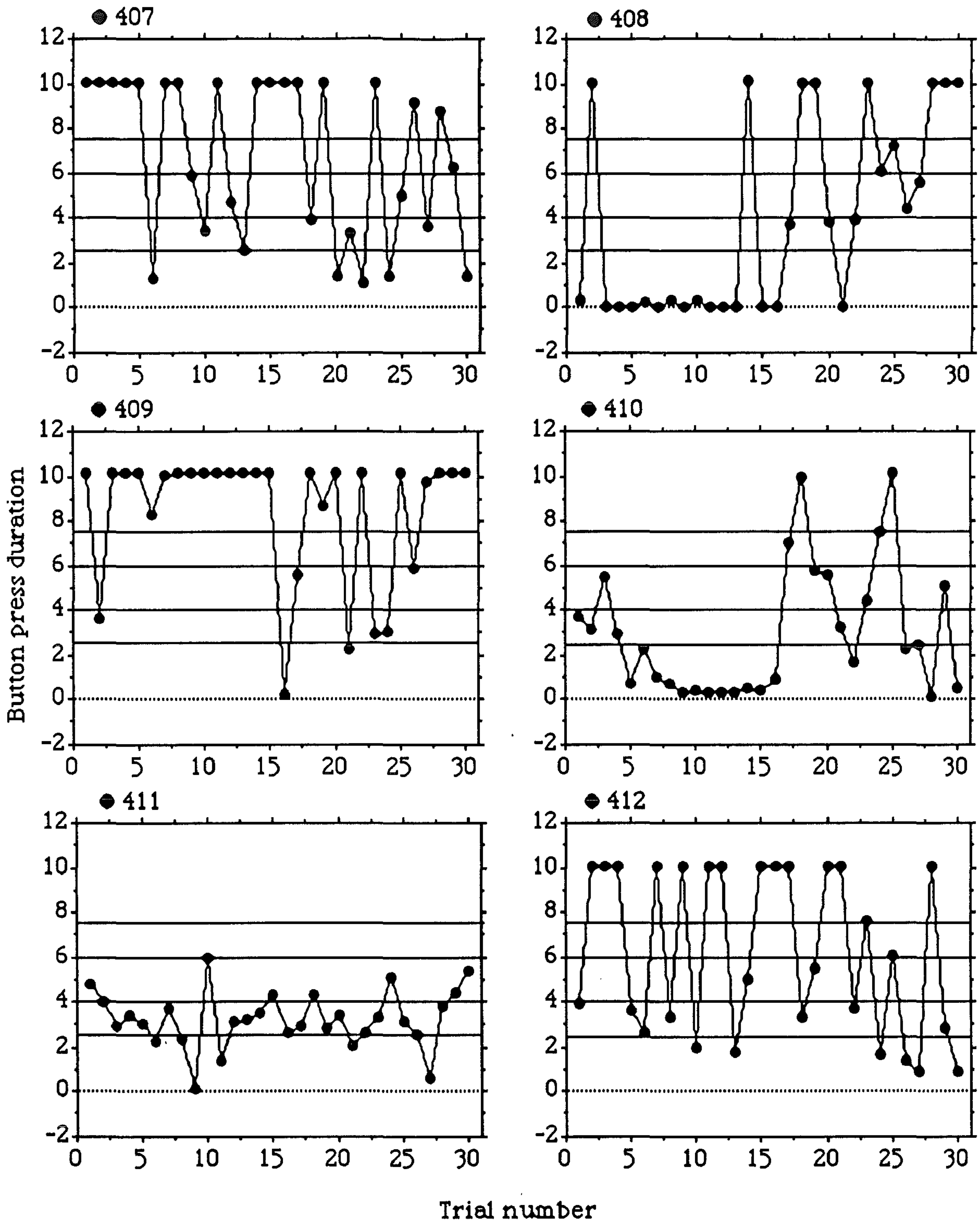
In the second pilot investigation there was evidence of task acquisition, but for those subjects who failed to acquire the task the modal response was to press the button for the maximum possible time. That is, unsuccessful subjects were failing to let the button go. This may have been at least partially a result of presenting feedback on the two practice trials while the subjects were pushing the button. Thus in the practice trials for the final procedure, the experimenter told subjects when to release the button so that reinforcement was contingent on letting go of the button after holding it down for 5 seconds.

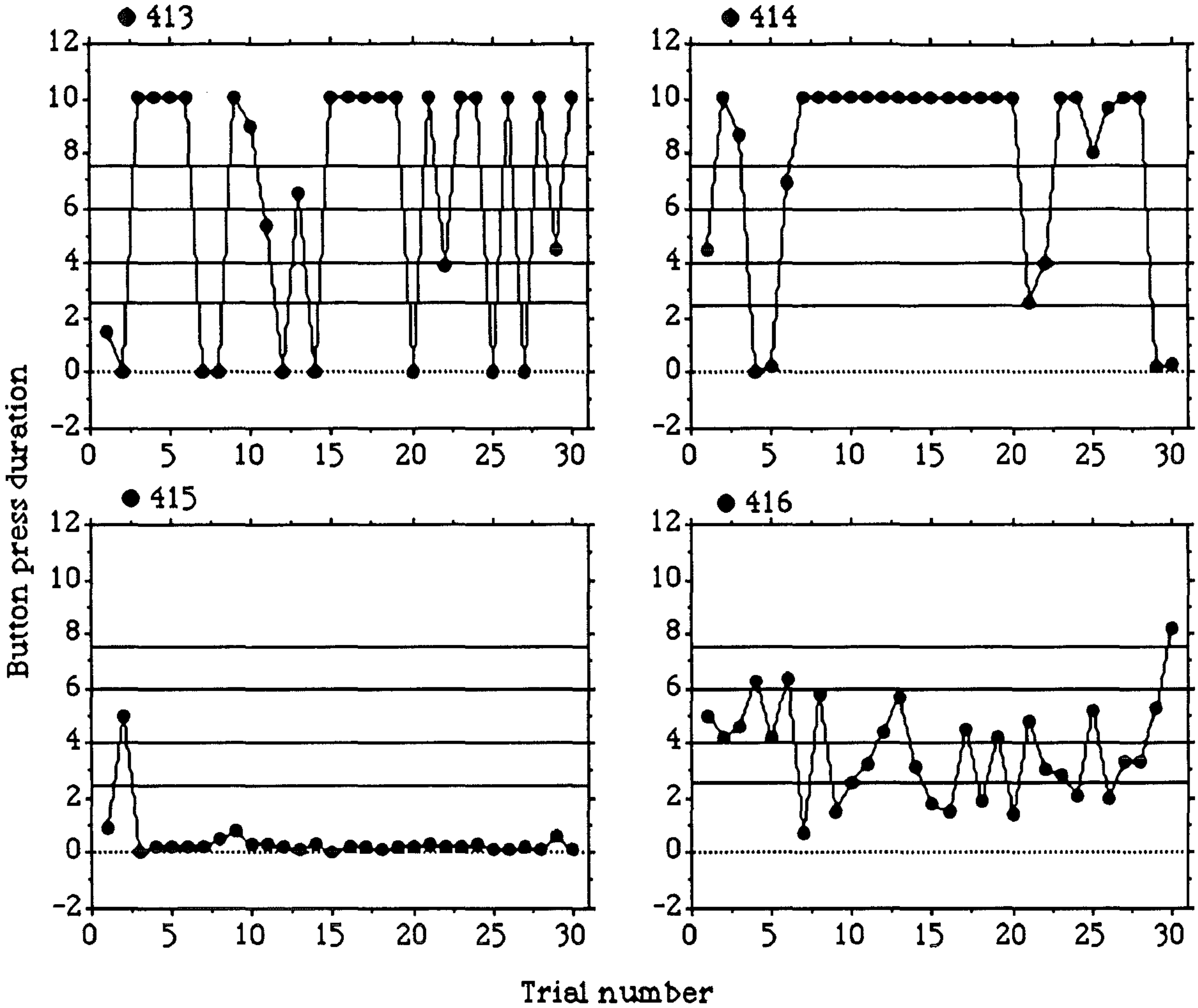
APPENDIX C

Line graphs for each subject showing button press duration for each of the 30 trials. The horizontal lines show the boundaries for successful button presses, such that button press durations of 2.5≤ x <4.0s and 6.0< x ≤7.5s result in "okay" feedback, and durations of 4.0-6.0s result in "very, very good" feedback.

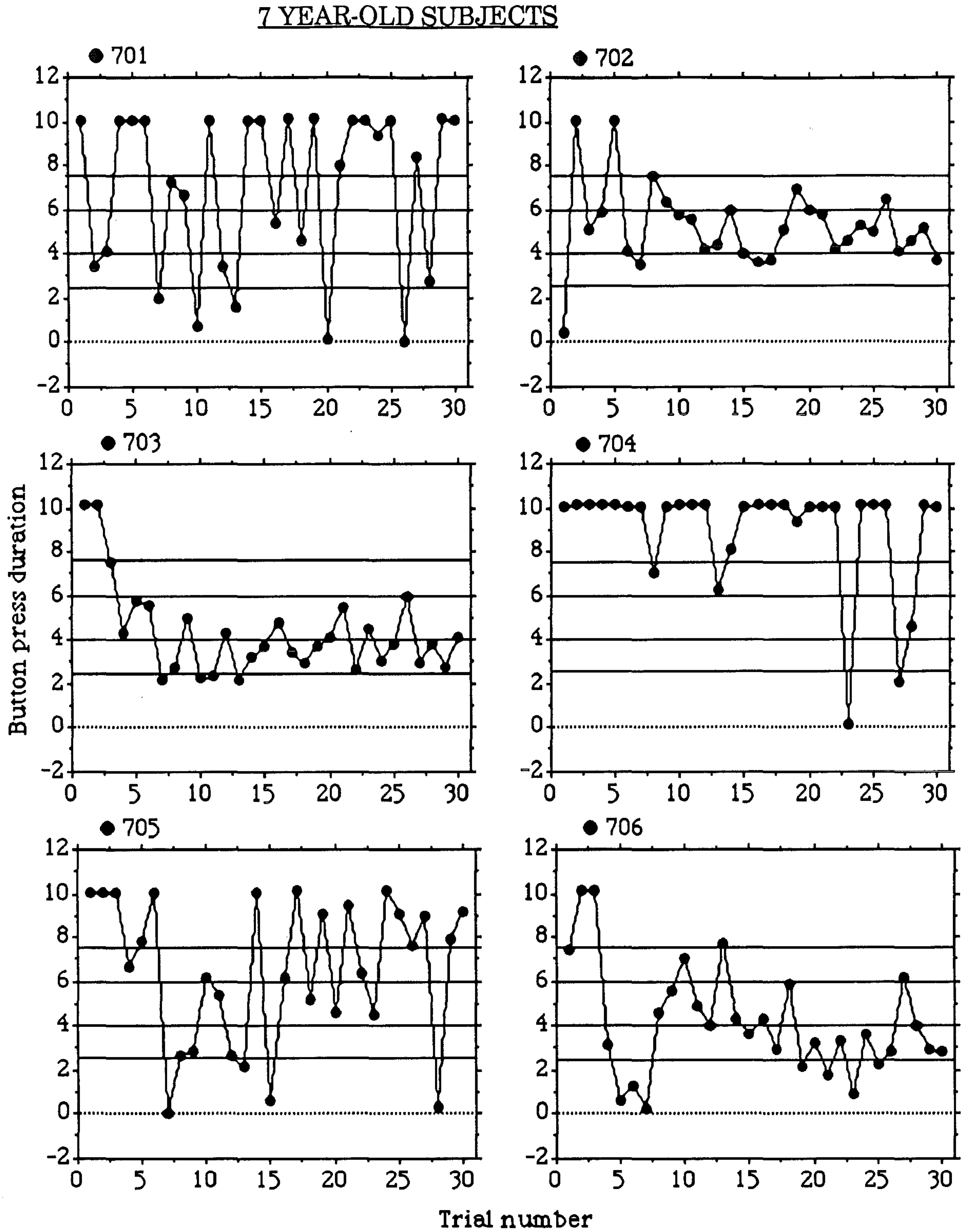
4.5 YEAR-OLD SUBJECTS

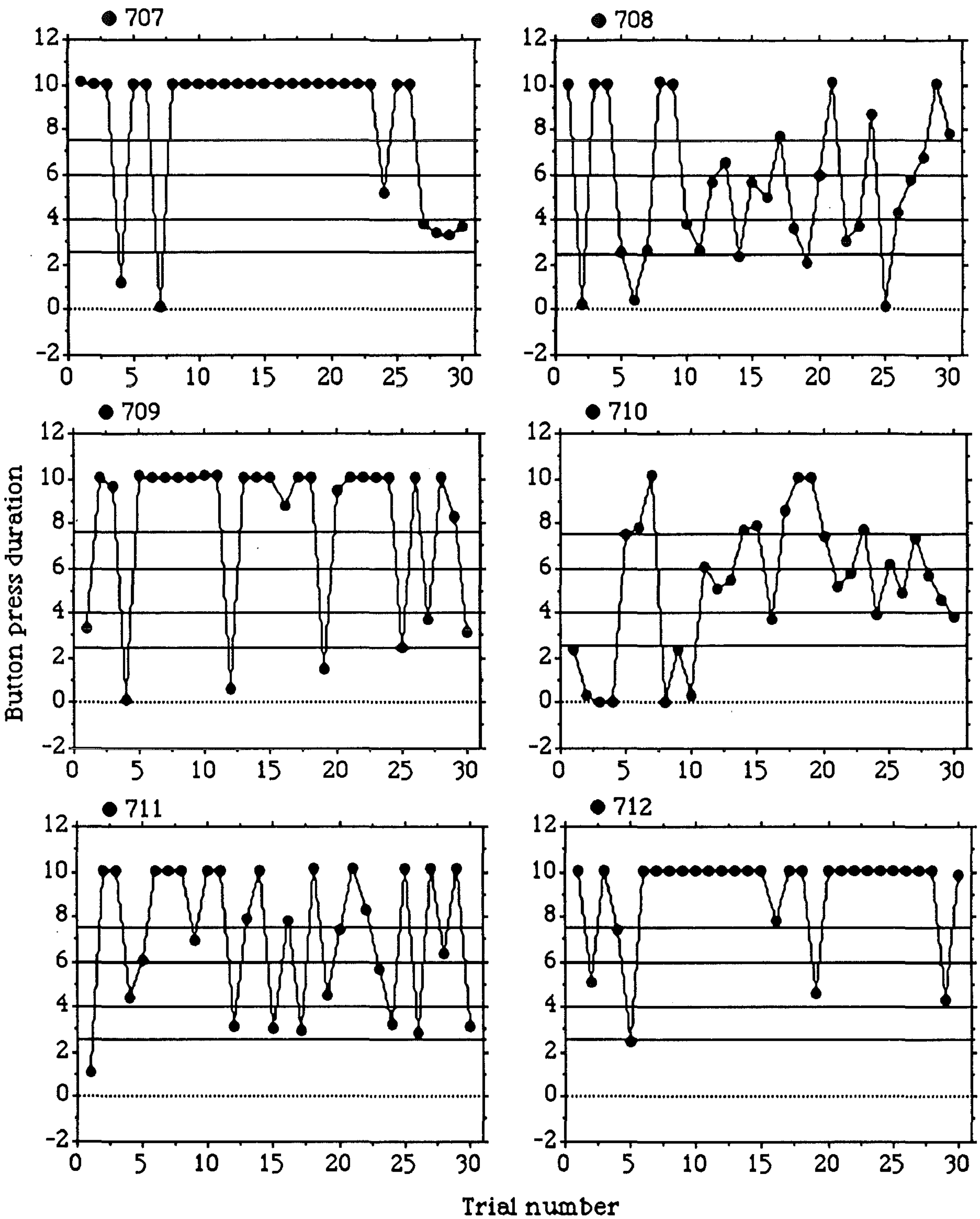


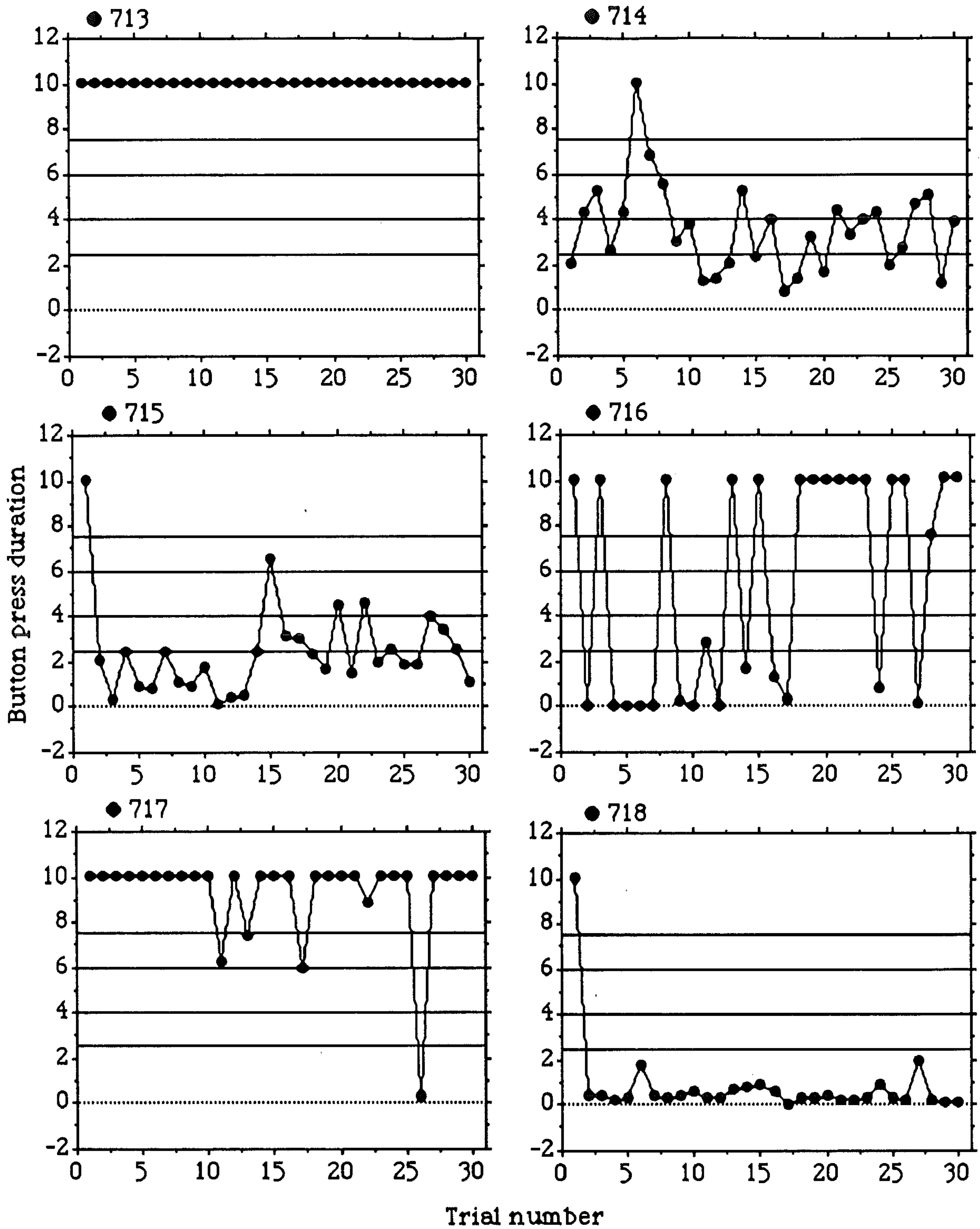

407
408
409
410
411
412
Button press duration
Trial number

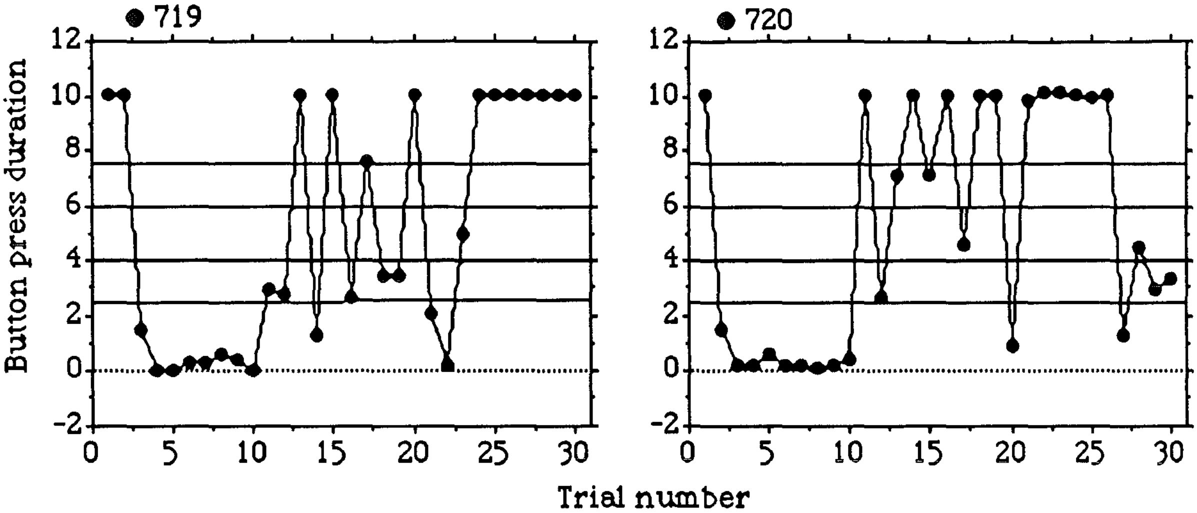


413
414
415
416
Button press duration
Trial number


7 YEAR-OLD SUBJECTS
701
702
703
704
705
706
Button press duration
Trial number
12
10
8
6
4
2
0
-2
0
5
10
15
20
25
30

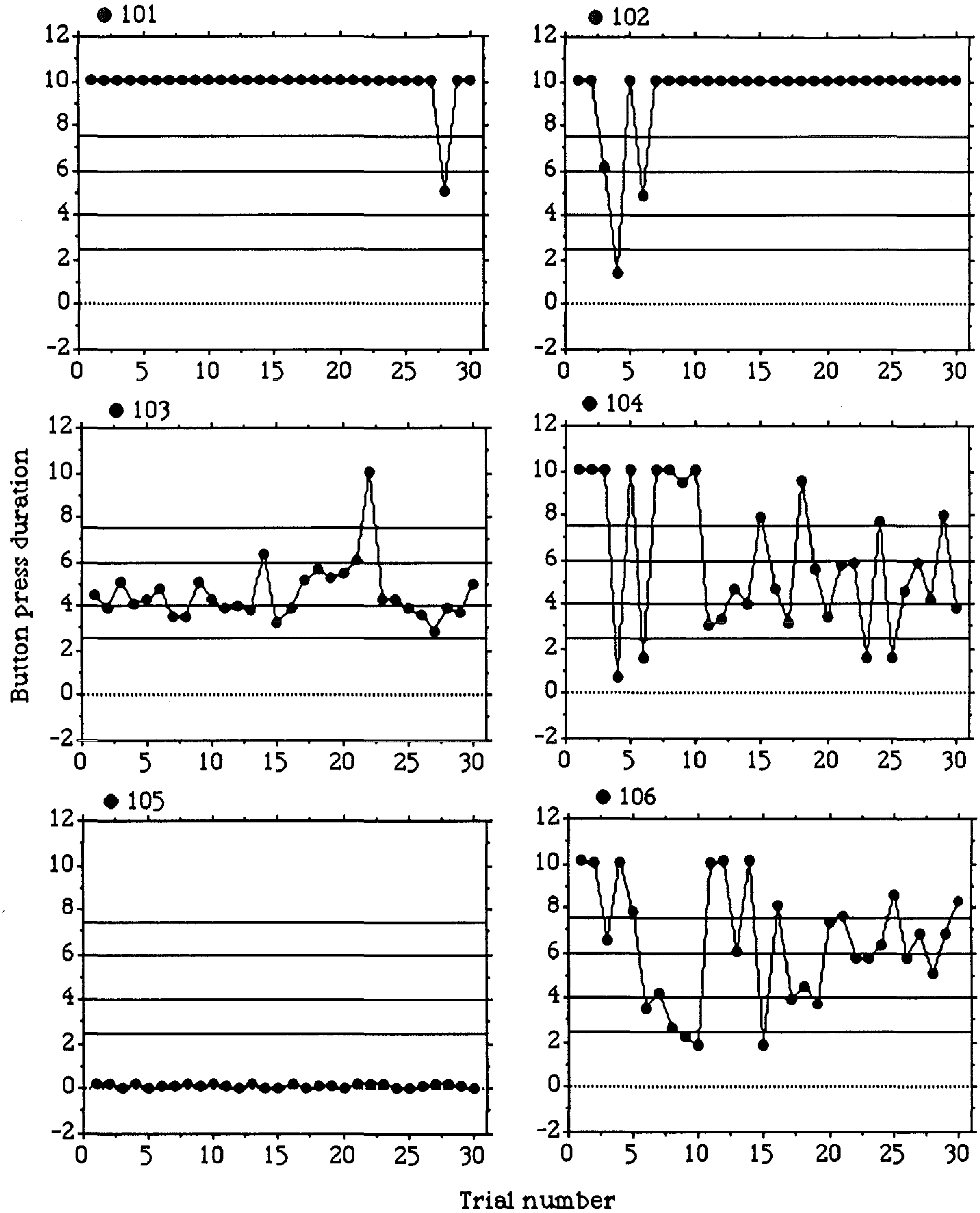

707
708
709
710
711
712
Button press duration
Trial number

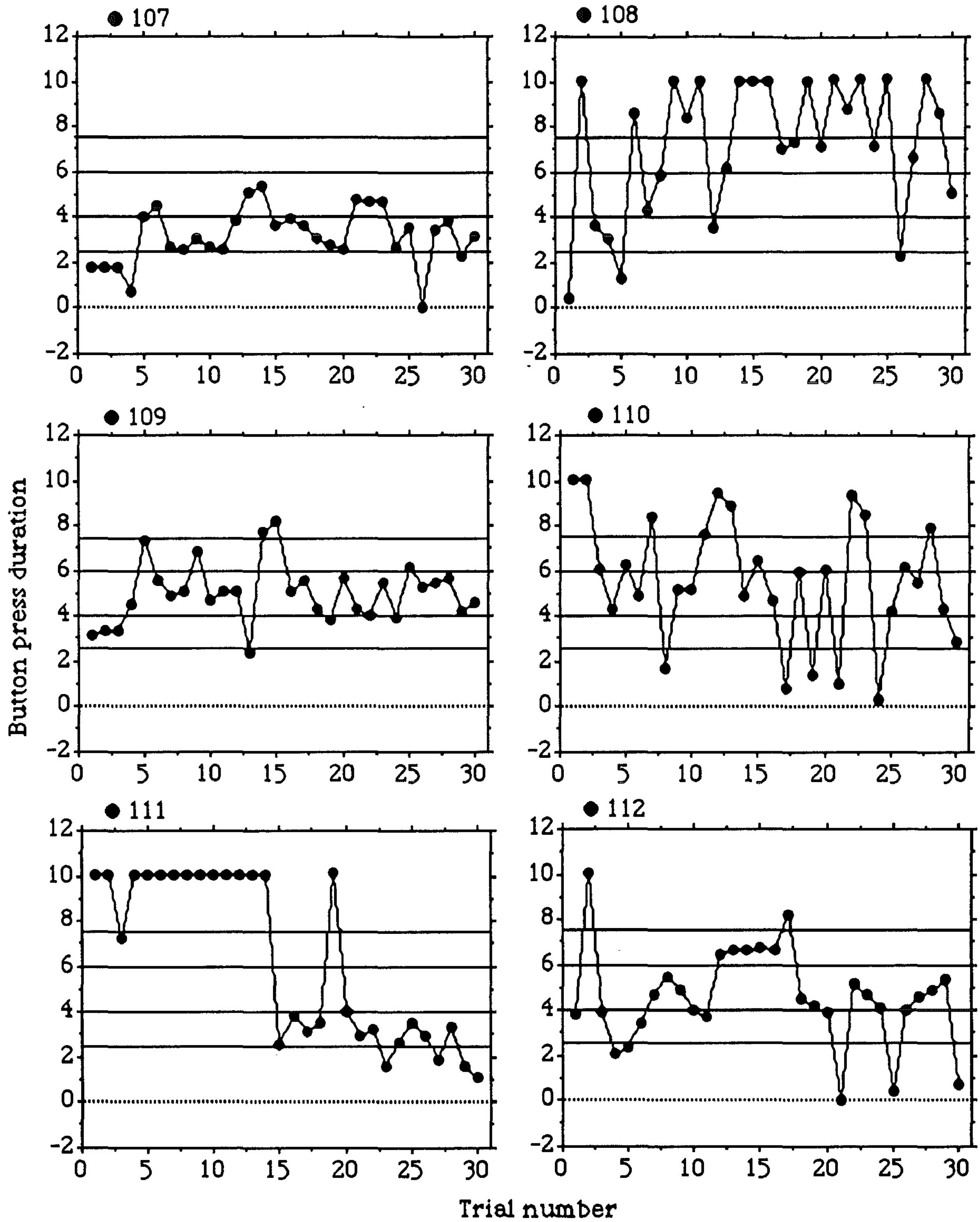

713
714
715
716
717
718
Button press duration
Trial number
12
10
8
6
4
2
0
-2
0
5
10
15
20
25
30

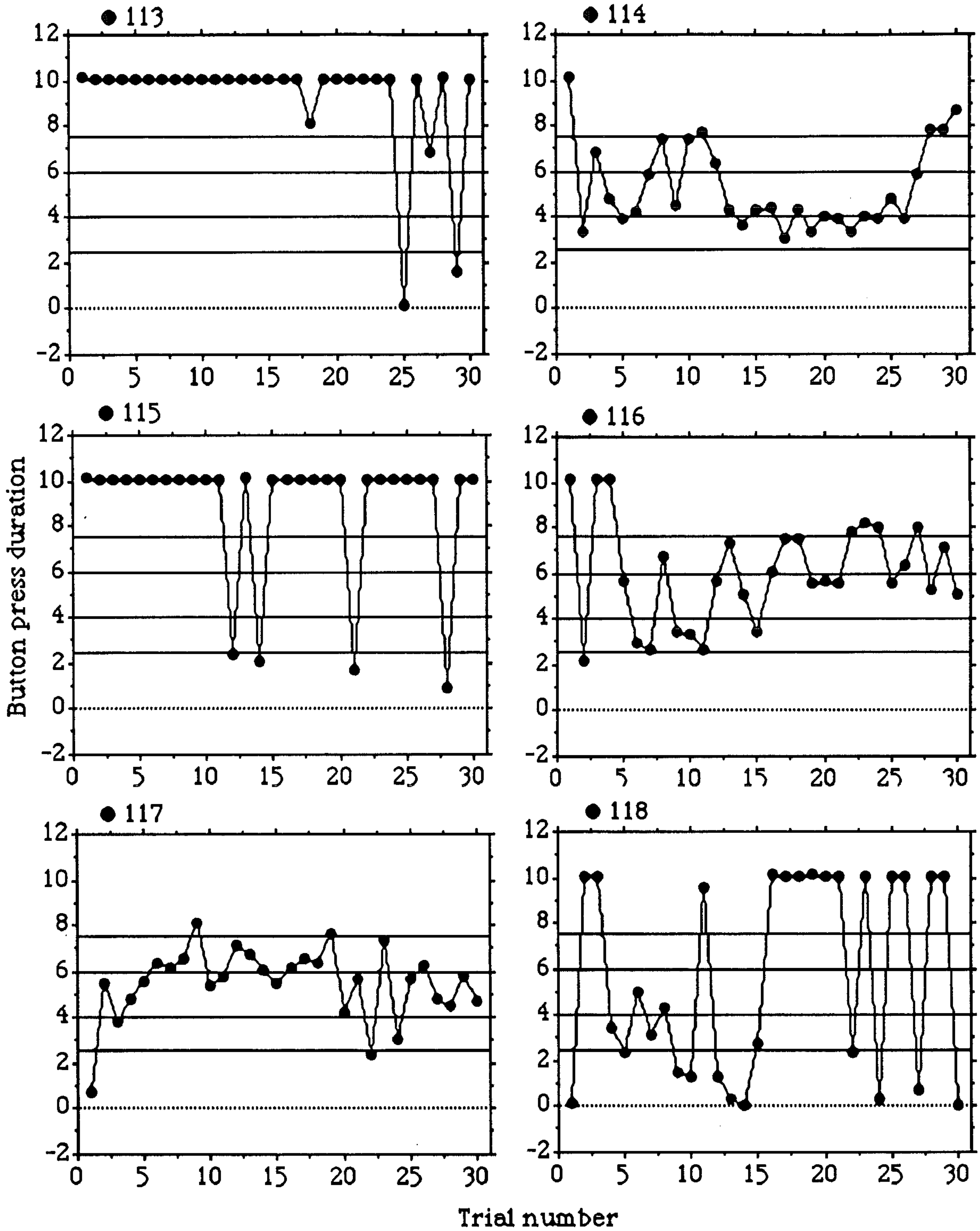


719
720
Button press duration
12
10
8
6
4
2
0
-2
0
5
10
15
20
25
30
Trial number

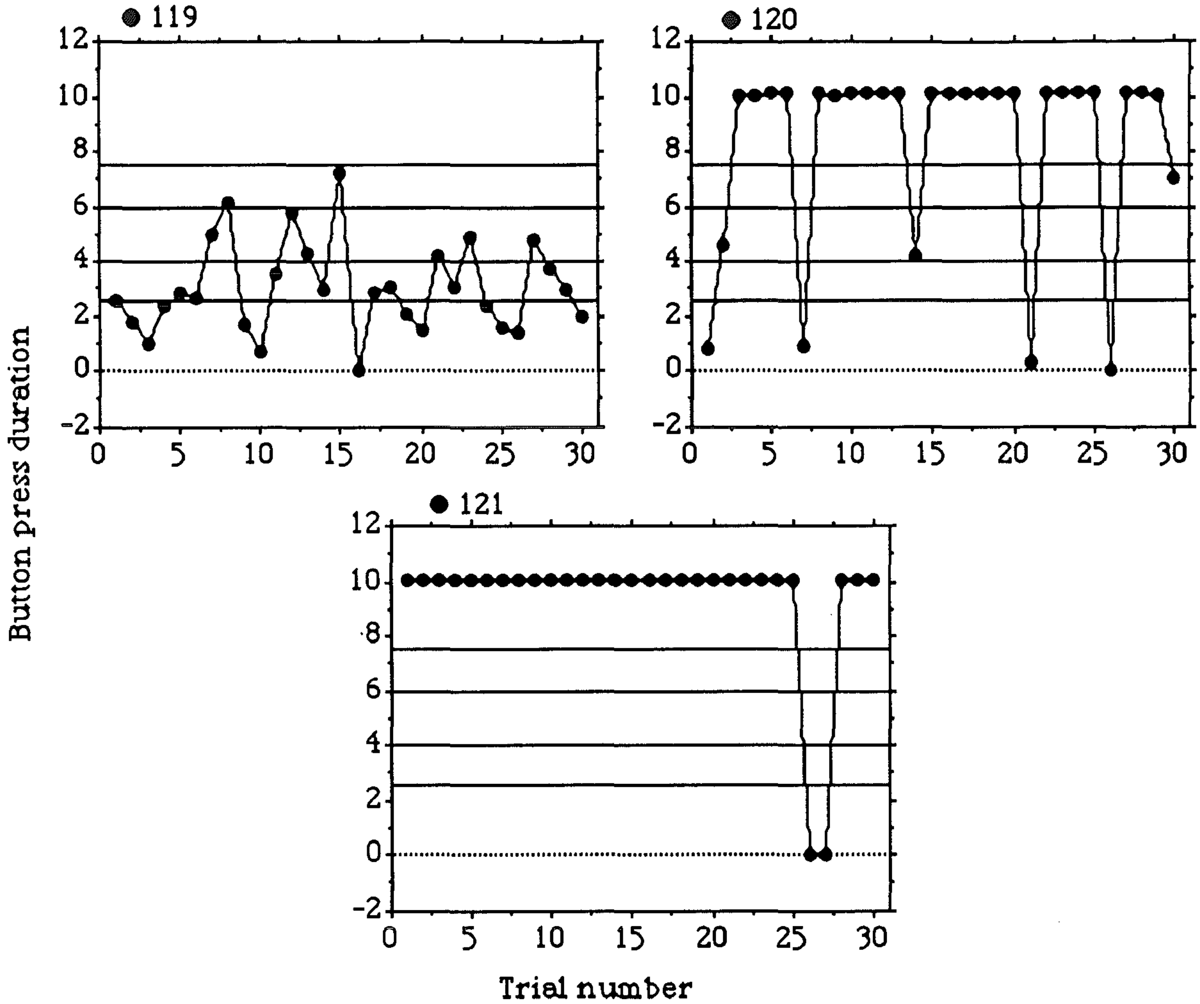
11 YEAR-OLD SUBJECTS




107
108
109
110
111
112
Button press duration
Trial number



113
114
115
116
117
118
Button press duration
Trial number


119
120
121
Button press duration
Trial number
12
10
8
6
4
2
0
-2
0
5
10
15
20
25
30